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COMPARISON OF MILITARY AND COMMERCIAL DESIGN-TO-COST AIRCRAFT PROCUREMENT AND OPERATIONAL SUPPORT PRACTICES

MCDONNELL DOUGLAS CORPORATION
DOUGLAS AIRCRAFT COMPANY
3855 LAKEWOOD BLVD.
LONG BEACH, CALIFORNIA 90846

APRIL 1976

TECHNICAL REPORT AFFDL-TR-75-147
REPORT FOR PERIOD MAY 1975 – JANUARY 1976

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION IS UNLIMITED

AIR FORCE FLIGHT DYNAMICS LABORATORY
AIR FORCE WRIGHT AERONAUTICAL LABORATORIES
Air Force Systems Command
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This technical report has been reviewed and is approved.

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This technical report examines the procurement and support practices of selected commercial/military program pairs. It is intended to identify those military practices that are cost drivers and to determine if substitution of selected commercial practices would reduce program costs. The study draws heavily on the DC-8/AWACS and the DC-9/C-9 program pairs. Comparisons include all major program phases from initial planning to operations and support. For certain specific findings, recommendations are made which could contribute materially to lower costs for military programs.

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PREFACE

This report was prepared by the Douglas Aircraft Company of the McDonnell Douglas Corporation under USAF Contract No. F33615-75-C-3139. The contract was administered under the direction of the Air Force System Command (AFFDL/FXC) with Nathan L. Sternberger as Project Engineer. The work was initiated under Project No. 12070144, "Identification of Aircraft Systems and Program Improvements Leading to Support Cost Reduction".

The Principal Investigator for the Douglas Aircraft Company was Mr. L. Carlyle and the contractor's report number is MDC J7064.

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SUMMARY, FINDINGS, AND RECOMMENDATIONS

This study was made to identify specific military program practices that drive the costs of these programs upward and to determine if less costly commercial practices exist that could be substituted. The study was limited to military derivatives of commercial aircraft and is therefore concerned chiefly with the derivation of the C-9A/B/C versions of the DC-9 and the AWACS version of the DC-8. Where pertinent, references to other military and commercial programs are included.

This report contains an analysis of pertinent literature prepared for in-house Air Force studies, Air Force funded studies and various high-level DOD task force studies. A summary of responses to a questionnaire reveals company management attitudes regarding program practices. The number and impact of military regulatory controls on design, manufacturing and testing functions are discussed. Comparisons are made of commercial and military program practices from Initial Planning through Operations and Support. A comparison between a full-military procurement and a hybrid military/commercial procurement for the AWACS air vehicle shows that the latter approach would reduce the schedule by 15 months and the design and development effort by more than 2 million engineering hours - a saving in excess of $46,000,000.

Specific findings relative to military and commercial practices and attendant recommendations for application to military derivative programs follow:

1. Data Items
   a. Finding: The kinds and quantities of contractual data items required for military programs greatly exceed those developed for comparable commercial programs (Sections II-C, III A-3).
   b. Recommendation: Reduce the categories of contractual data items, copies thereof and preliminary submittals, to those actually necessary for decision-making for the specific program phase.

2. Government Personnel

   a. Finding: Delegation by the SPO of certain program authority to the resident NAVPRO and the local FAA on the C-9A, C-9B, and VC-9C programs avoided excess paperwork and delays and resulted in efficient programs without large SPOs (Section III A-4).

   b. Recommendation: Transfer authority for day-to-day decisions to resident and local offices of military plant representatives and FAA to shorten communication lines, reduce paperwork and to provide fewer, but more direct, personnel interfaces.

3. Configuration Management

   a. Finding: The generation of scores of specifications in various levels of detail, all in MIL-STD format, and the controlling of them in accordance with specified government procedure is costly and inhibits design improvement (Section III A-5).

   b. Recommendation: Simplify configuration management process by maximizing use of existing contractor and vendor item specifications and internal procedures and delay formal control until design freeze.

4. SPO Personnel

   a. Finding: DOD Program Managers and other key SPO personnel are often insufficiently experienced, do not have clear-cut decision-making authority and are rotated in accordance with duty cycles instead of major program phases (Sections II A-1, III A-2).

   Recommendation: Select key personnel on basis of experience and effectiveness, establish their authority for program decision-making to permit required flexibility and assign them in accordance with major program phases.

5. SPO Role

   a. Finding: Military practice demands an extreme amount of visibility and control in areas such as design and manufacturing which are well established on derivative programs and therefore are costly to change (Section III A-1, III A-3).

b. Recommendation: Redirect SPO role toward program-level decision making instead of spending government and contractor time in areas that are well-established and are not subject to much change, and in which the government personnel often have insufficient expertise.

INITIAL PLANNING

1. Scope and Level of Detail
   a. Finding: The scope and level of detail developed for military pre-acquisition studies are not commensurate with the general requirements for these program phases (Section III B-2, 3).
   b. Recommendation: Limit Conceptual Phase technical activities to those necessary to identify system requirements, establish a feasible technical approach, determine availability of required technology and identify high risk areas. Limit Validation Phase activities to those necessary to define Acquisition Phase design and production approaches within reasonable limits.

2. Government Reviews
   a. Finding: The imposition of formal reviews during short duration, fixed-price studies is costly and detracts from study efforts (Section III B-3).
   b. Recommendation: Negotiate fixed-price studies on the bases of related contractor approach to development of required study products and related experience, then limit or avoid interruptions during the contract term.

DESIGN ENGINEERING

1. Military Specification Applicability
   a. Finding: Military specifications are applied as though all programs have the same objectives and will experience the same problems. That is, a military derivative of a mature commercial aircraft is subject to the same detailed design an test specifications as a new tactical aircraft. To avoid costly redesign and/or requalification of proven airframes, contractors often must expend considerable time and resources to justify deviations from contractually imposed military specifications and standards. Delays in approvals also may force costly redesign effort (Section II C, III C-1).

b. Recommendation: Government agencies should request prime contractors to identify the specifications and standards thought to have production applicability and to provide a complete set of specifications for government review at PDR and approval at CDR. The use of commercial and vendor specifications to which the base aircraft was designed, tested and certified should be strongly emphasized.

2. Design and Development Data

a. Finding: Military derivative programs often require the generation of new data and the regeneration of existing design and development data in specific military report formats (Sections III A-3, III E-1).

b. Recommendation: Accept existing commercial documentation formats relating to an aircraft's successful commercial use in lieu of developing new data where none was developed originally.

MANUFACTURING/PRODUCTION

1. Production Line Changes

a. Finding: Seemingly minor changes to the manufacturing and assembly processes of an existing airframe often cost more than the anticipated benefit is worth (Section III D-1).

b. Recommendation: Maintain existing production processes to the maximum extent and carefully evaluate costs of desired changes against benefits to be gained.

TEST/EVALUATION

1. Full Scale Structural Integrity Tests

a. Finding: The military requirement for a full-scale structural integrity program on a derivative development may cost millions of dollars more than a comparable commercial derivation (Section III E-1).

b. Recommendation: Utilize more fully the proven commercial practice of detailed analysis of design changes, followed by sufficient ground and flight testing to validate selected cases.

2. System Performance Demonstrations

a. Finding: Continuous, full-blown formal analysis and test programs for reliability, safety, personnel subsystems, etc. during design development often results in negation of previous work and addition of new work as the configuration changes (Section III E-3).

b. Recommendation: Defer -"ility" demonstrations until initial operational phase, conduct sufficient analyses and tests during development to support design and to establish goals for system acceptance.

OPERATIONS AND SUPPORT

1. Contractor Support

   a. Finding: The C-9A Contractor Support Program has been highly successful in terms of high operational availability with maintenance costs which are lower than those estimated for equivalent organic support (Section III F-1).

   b. Recommendation: Expand the application of contractor support to the maximum number of non-vital as well as selected vital systems.

2. Maintenance Intervals

   a. Finding: Military maintenance checks are based on a calendar basis, therefore, with low utilization, the elapsed flight hours are extremely low compared to commercial practice which is based on hours flown (Section III F-2).

   b. Recommendation: Lengthen current maintenance intervals, reaudit certain maintenance actions to the next higher level of check or base maintenance actions on flight hours.

3. Maintenance Analysis

   a. Finding: Advanced maintenance analysis techniques have drastically reduced the "hard time" maintenance actions on commercial aircraft even though the complexity and parts count has increased markedly (Section III F).

   b. Recommendation: Implement procedures of Air Transport Association Maintenance Program Planning Document MSG-2.

4. Engine De-Rating

   a. Finding: Many commercial operators reduce their engine maintenance costs significantly by using reduced power settings for takeoff and climb when operating below the payload/range capability of the aircraft (Section III F-2).

b. Recommendation: Reduce takeoff and climb power settings when operating conditions permit.

SECTION I
INTRODUCTION

There is a widely-held opinion that certain procedures in the planning, procurement and operation of military systems are significantly more costly than the comparable commercial procedures. This opinion served as the basis for this comparison of military and commercial procedures on selected program pairs.

The objectives of the study, as described in the Statement of Work, were: " . . . to identify those commercial aircraft procurement and logistic support techniques, practices and procedures which, if applied to military aircraft procurement, will result in significantly lower acquisition and operational support costs. Conversely, those military aircraft procurement techniques, practices and procedures which are cost drivers and result in high unit fly-away and life cycle support costs will be identified. . . Comparative evaluation of the selected aircraft will include identification of significant differences and the impact of the differences on the life cycle phases and their cost and on total program costs."

The five principal study tasks were as follows:

Task 1: Technology Data Base
Develop the military and commercial data base required to conduct the study and needed to identify and analyze those acquisition and support practices used by commercial businesses which would help reduce the costs of military aircraft programs.

Task 2: Analysis and Comparison of Military and Commercial Practices
Using the technology data base compiled as required by Task 1, examine, analyze, identify and compare the acquisition and support practices in each program studied to the various management phases including planning, design, development, test and evaluation, manufacturing/production, and operations and support.

Task 3: Feasibility Evaluation Study

Analyze the extent of the differences identified in Task 2 and determine the cause and program impact of each difference within each of the phases detailed in that task. Using the information developed, evaluate the feasibility and practicality of modifying present military acquisition and support practices and procedures; and/or of adopting existing or some modified variation of unique commercial practices to defense procurement and operational support.

Task 4: Impact Analysis

Analyze and compare the differences in military and commercial acquisition and support practices in terms of cost, flow time and resources and evaluate the impact of the commercial practices identified for application to military programs in these same terms.

Task 5: Study Product

The analyses and evaluations derived from this study shall be the basis for developing recommendations regarding the feasibility and practicality of modifying military procurement and support practices and procedures which contribute materially to high acquisition and operational costs and/or applying certain high payoff commercial practices to military programs to achieve reduced costs.

The study flow diagram shown in Figure 1 relates these tasks.

The study was limited to derivative configurations on selected program pairs. It was believed that this would provide the most direct, readily understood comparison. Recent military derivative programs involving the Douglas Aircraft Company produce line are limited to the C-9A/B/C derivatives of the DC-9 and the AWACS derivative of the DC-8; the AWACS experience includes the submittal of a Contract Definition Phase study report and a proposal for acquisition. Therefore, the Douglas study drew heavily on these programs.

The AWACS derivative of the DC-8 and the C-9 derivatives of the DC-9 were compared to specific commercial versions of these aircraft, the DC-8-61 and the DC-9-31, respectively. Where pertinent, data on the DC-10, Advanced Medium STOL Transport (AMST), and the Navy Land Based Anti-Submarine Warfare Patrol Aircraft (VSX) were included.

In this study, differences in military and commercial practices are quantified both in terms of dollars and man-hours. The dollar values have been developed in accordance with the composite aerospace industry rates described in Reference A1-1 to avoid the possibility of revealing financial strategies on past programs.

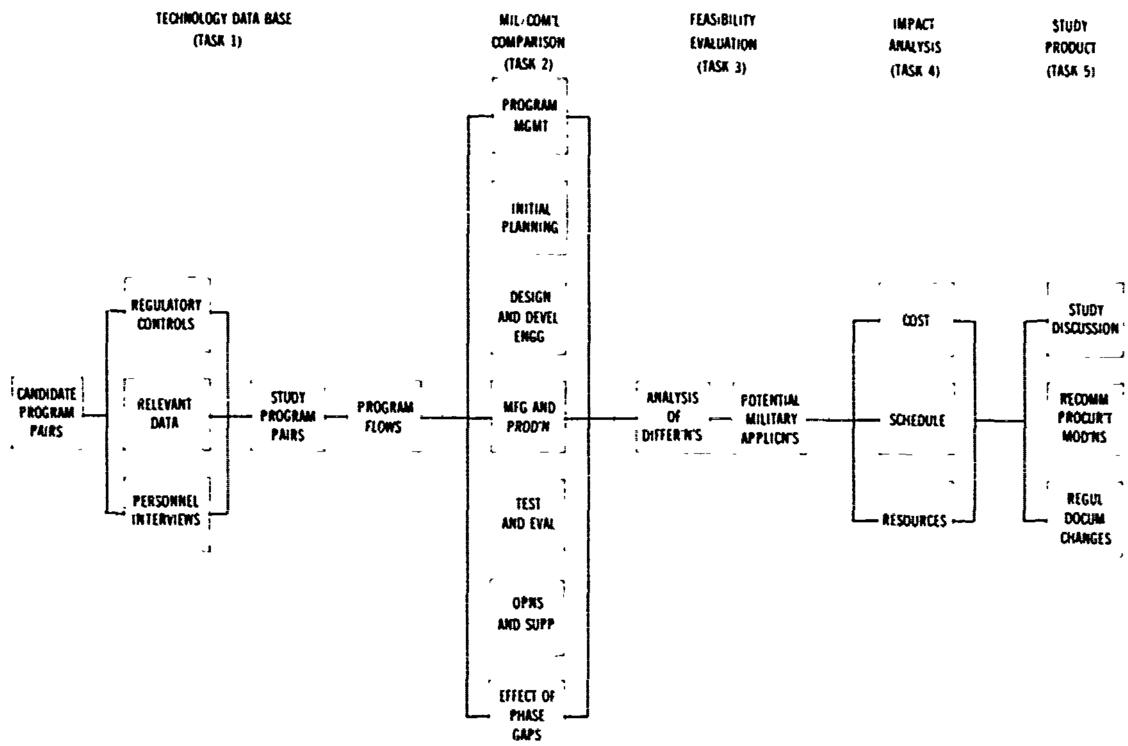


Figure 1. Study Flow Diagram

SECTION II

TECHNOLOGY DATA BASE

Task I of the study concerns the establishment of a data base adequate for subsequent analyses. This data base consists of extracts from the existing literature, personal interviews and questionnaires filled out by persons cognizant in the various program functions, extracts from the documentation of previous programs, and a rationale for equating the aircraft being compared. In this section the data thus developed are discussed. Analyses and interpretations of the data are covered in Section III.

A. LITERATURE SEARCH

Many reports were reviewed to determine those which relate specifically to the subject of this study. An overview of several significant studies is presented first, followed by a synopsis, findings, and recommendations for each relevant study. <u>No attempt has been made in this report to justify or evaluate the findings of these previous studies</u>.

1. Overview

Concern over the steadily increasing costs of new weapons systems is indicated by the number of major studies and the high level statures of the study groups employed to perform the studies. Some study groups have been appointed by, and reported directly to, the President of the Senate and Speaker of the House of Representatives, while others have reported directly to the Secretary of Defense and to the President. The U. S. Congress, deeply concerned with the spiralling costs of major acquisitions, has appointed various commissions and study groups in attempts to determine new procedures to reduce defense spending.

Only one of the studies directly addressed a comparison of commercial versus military procurement and support practices. Most studies were initiated in response to problems of a specific nature or to cover a general problem category peculiar to a command or office within the Air Force or the government. Despite the variety of subjects studied and the range of personnel involved (congressmen, business executives, military) certain findings were common and are summarized in Table I.

TABLE I. LITERATURE SEARCH SUMMARY

STUDY SHORT TITLE	PROGRAM MGMT. LONGEVITY, AUTHORITY NEEDS REVISION	PROGRAM/ SYSTEM DEFINITION NEEDS IMPROVEMENT	EXCESSIVE PAPERWORK/REPORTS, MIL-SPECS., TOO MUCH DETAIL	COST JUSTIFICATION vs COST REDUCTION, CURRENT PROCEDURES ELIMINATE POSSIBILITY OF LAT
A. – LESSONS LEARNED FROM AF MANAGEMENT SURVEYS	X	X	X (375 – SERIES IMPLEMENTED)	X
B. – TOTAL PACKAGE ACQUISITION CONCEPT	X	X	X	
C. – ASSESSMENT OF CD AND TPP	X	X	X	
D. – REPORT BY BLUE RIBBON DEFENSE PANEL	XX	XX	X	X
E. – REPORT – COMMISSION ON GOVT PROCUREMENT	XX	XX	XX	X
F. – REPORT ON REDUCING COSTS DEF SYS ACQ	XX	X	XX	XX
G. – PROJECT ACE	XX	XX	XX	XX
H. – PERFORMANCE CONTROL			XX	

X STUDY FINDING/RECOMMENDATION

XX SUBJECT EMPHASIZED

Some studies placed particular emphasis on one or more of the findings/ recommendations, with Program Management receiving most attention. A universal recommendation was to provide the SPO with adequately experienced personnel and authority to make program decisions. Another recommendation was to reduce excessive paperwork through less formal reporting, to require fewer data items and to eliminate "How to" MIL-SPECS. A third common recommendation addressed the subject of Program/System Definition and in essence stated there should be complete understanding and full concurrence among and between all control agencies prior to issue for contractor action. A common-to-many-finding addressed the military-peculiar problem of cost justification versus cost redu cn. This problem usually generated by program over-runs, buy-in, or exceeding state-of-the-art, can be reduced, if not eliminated, by improved management procedures and more definitive program directives.

2. Abstracts

The following list of major studies includes reports of in-house Air Force studies, Air Force-funded studies and various high level DOD task force studies.

a. "A Summary of Lessons Learned from Air Force Management Surveys" AFSCP 375-2, dated June 1963.

Synopsis:

This study, performed by Air Force Systems Command, examined management policies, procedures, and practices, and the costs which result in charges against Air Force contracts. It provides a summary of lessons learned from a survey of twenty-four major contractors. It also provides a critical assessment of Air Force program management and procedures.

Findings and Recommendations:

Program Management is complicated by conflicts and duplication of functions between functional organizations and by layers of decision-makers. This finding is applicable to both the military and contractor organizations. Vertical program management organization is recommended with clear-cut channels between the SPO and contractor program manager.

Subsystem development is complicated by inadequate definition in the initial work statement. This leads to problems in definition of support systems, spares, and test procedures and generates excessive paperwork which further complicates the management process.

Corrective recommendations included more complete equipment definition during early program phases coupled with contractor management teams experienced in engineering, material and quality control assigned to each major subcontractor.

b. "Total Package Acquisition Concept", Logistics Management Institute Task 65-31, dated November 1965.

Synopsis:
This study concentrated on the procedures and efforts of the C-5 prime contractors (three airframe and two engine) and subsystem contractors. Interviews with both management and engineering personnel provided a broad consensus of opinions on the value to the government and on problems generated for contractors by the Total Package Acquisition (TPA) concept employed for the C-5. The timing of the study, starting just before contract award to Lockheed and ending within a year, provided results based only upon contracting activity prior to start of production. The majority of comments were favorable to the TPA concept as being "much like" commercial practice. Unfavorable comments were related to the timing for definition of support requirements (AGE, etc.) and to the risk involved in early definition of life cycle support for a system not completely defined.

Findings and Recommendations:
Findings and Recommendations, limited to TPA, are: (1) lack of decision-making authority and experience in the SPO, (2) inadequate program/system definition during CD and early design phase (i.e., lack of total agreement in Air Force Control Offices), (3) excessive reporting due to control procedures and over-specification created by compliance with MIL Specs. The Total Package Acquisition concept was "more like" commercial practice - but with more control by military requirements which in turn create increased costs. A major finding of the study was that TPA tends to increase the costs when initiated in the CD phase and may not be appropriate for many programs since deployment concepts may not be firm or production quantity may be in question.

c. "An Assessment of Contract Definition and Total Package Procurement", USAF Ad Hoc Group, dated 31 January 1967.

Synopsis:

This study addressed the relative resource requirements for Contract Definition and Total Package Procurement (TPP) versus prior contracting procedures. The results of implementing the 375-series and other regulations specifying TPP policies were examined to determine the effort required over past procurement methods, gains in terms of improved procurement, recommended extent of implementation of alternative procurement methods, determination of manpower differences by program phases, and whether or not decentralized review and approval would reduce time and effort in Contract Definition while attaining contract objectives.

Findings and Recommendations:

Findings and recommendations of the study group were tempered by a lack of experience data upon which a final decision could be predicated. Even though questions relating to this current study were answered only in a tentative manner, the following recommendations were presented: (1) Contract Definition and Total Package Procurement procedures appear to offer improvements over past methods and should become the prescribed method of normal procurement operation, (2) Major policy changes should include more authority for decision-making by the designated source selection authority and the SPO, with direct communication between the SPO and the decision-maker, (3) Evaluation criteria should be specified in the RFP and source selection evaluation criteria should be limited to items which can be clearly identified and measured.

d. "Report by the Blue Ribbon Defense Panel to the President and the Secretary of Defense on the Department of Defense", Aerospace Industries Association Administrative Memo No. 70-33, dated 28 July 1970.

Synopsis:
This report resulted from a year long study dealing with the organization and procedures of the Department of Defense. The report contains 113 recommendations for changes in department procedures. While the subject study was not directed explicitly toward solutions of problems investigated for the current design-to-cost study, its peripheral conclusions and recommendations have significant impact on the planning and acquisition of all major weapons systems.

Findings and Recommendations:
The Blue Ribbon Defense Panel found that most program management organizations were too bulky for efficiency, with too many layers of decision-makers, and with final decisions usually required at Secretary of Defense level where it is impossible to obtain complete data for all programs. They also found that frequent rotation and reassignment of military personnel interrupt SPO organizations in critical program phases. The panel devoted its efforts mainly toward recommendations for sweeping reorganization of the Department of Defense, Military services and the academic organization with R&D facilities. Many recommendations relating to procurement procedures were made, including abolishment of Total Package Procurement.

e. "Report of the Commission on Government Procurement", dated 31 December 1972.

Synopsis:

The commission included membership from both the legislative and executive branches and from a variety of industrial organizations. A staff of about fifty professional members conducted the study which concentrated on three specific areas of the procurement process: (1) The environment in which procurement occurs (the organizations and authority and controls under which they operate), (2) The sequence of procurement events and (3) Types of procurement (R&D, major systems, commercial products, and construction). The four volume report placed emphasis on the four problem categories; management, system definition, excess paper/reports, and reduction of costs versus justification of costs as prescribed by fixed systems/fixed price bid.

Findings and Recommendations:

The study resulted in 149 recommendations for change/improvement in Government procurement procedures. Primary recommendations of the commission dealt with strengthening the organization for management of procurement procedures. Other findings and recommendations recognized the importance of adequate training and longevity for contract control personnel and more direct contact between contractor and decision-makers. They also recognize the problems generated for production contracts which provide equipment beyond state-of-the-art. Other major recommendations were related to:

(1) Establishing a common framework for conducting and controlling all acquisition programs that highlight key decisions for all involved organizations - Congress, agency heads, agency components, and the private sector, (2) Defining the role each organization is to play in order to exercise its proper level of responsibility and control over acquisition programs, (3) Providing visibility to Congress and agency heads by giving them the information needed to make key program decisions and committments.

f. "Design-to-Cost, Commercial Versus Department of Defense Practice", Defense Science Board Task Force Report, dated 15 March 1973.

Synopsis:

Study membership consisted primarily of high level representatives from major industrial organizations. The report addresses many major differences between Military and Commercial procurement practices. Its candid approach and open discussion of procedures make it a candidate for compulsory reading by procurement personnel.

Findings and Recommendations:

The ten principal recommendations, if implemented by DOD, would provide at least partial solutions to many major military procurement impediments. These recommendations place emphasis on both military and contractor action to motivate cost reduction in all phases of weapons system rather than to attempt cost justification after major expenditures have occurred. Specific recommendations deal with the tenure and qualifications of Program Managers, modification of the use of military specifications for many programs, strict control of the requirement for massive quantities of reports and documents, full definition of system requirements during early development phases, and other actions/recommendations designed to control procurement costs and procedures.

g. "Project ACE Findings and Actions", Air Force Systems Command (AFSC/AV) Report, dated July 1975.

Synopsis:

Project ACE (Acquisition Cost Evaluation) reports a major current effort by Air Force Systems Command to drastically reduce acquisition costs. High level working groups were charged with investigation of specific problem areas to determine changes which will result in reducing costs of the commands procurement activities. The report contains descriptions of the findings and summaries of actions being taken. Project ACE reference material lists some of the studies referenced in this section, and some recommendations of these prior studies have been integrated into the actions specified by the study activities.

Findings and Recommendations:
Project ACE describes further remedial efforts, in the form of new regulations, specifications and organizations which, if implemented, should improve the process used to manage military programs.

h. "Performance Control in Government R&D Projects: The Measurable Effects of Performing Management and Engineering Techniques", Edwin A. Gerloff, IEEE Transactions on Engineering Management, Volume EM-20, No. I, dated February 1973.

Synopsis:
This study examined the impact of a large number and variety of management and engineering techniques (such as PERT, value engineering, and configuration management) which have been implemented over the past decade to improve the technical, cost and schedule performance of government-sponsored R&D projects. The intent of the research was to determine if the imposition of management and engineering techniques resulted in a measurable difference in project technical, schedule and cost performance. The study utilized data collected from 108 Government-sponsored R&D projects which occurred in the 1950-1967 time period.

Findings and Recommendations:
(1) Intensive control can be ineffective in terms of performance improvement. The wholesale introduction of management control processes did not lead to better R&D project performance with reference to the project technical, schedule, and cost goals.

(2) Intensive control can be dysfunctional in terms of project technical and schedule performance. The intensive application of specific managerial control processes seemed to be accompanied by a degradation

of project technical, schedule and global performance goals, as well as requiring greater amounts of additional effort to achieve such goals.

(3) Project cost performance is more susceptible to effective control. Project managers who used specific control measures intensively did manage to enhance their cost performance relative to the cost performance of managers not using intensive control measures (though this result was not statistically significant). This is an interesting finding in view of the findings of other researchers, that the cost objectives have typically been sacrificed in favor of technical performance objectives. The type of performance most susceptible to control is the one which, in the past, has been regarded as less important.

(4) The intensive use of management and engineering techniques for control as presently required is of questionable value to project performance. Intensive managerial control efforts, at best, had no detectable effect on project performance, and at worst, resulted in a degradation of performance.

B. PROGRAM FUNCTIONAL FLOWS

As noted in the Introduction, recent applicable Douglas experience in military derivative programs involved production of the C-9A, C-9B and VC-9C versions of the DC-9, production of the YC-15 Advanced Medium STOL Transport Prototype, studies through Contract Definition of the AWACS version of the DC-8 and conceptual studies of the DC-10 Advanced Tanker Cargo Aircraft. These programs served as the basis for the major portion of this study

It is difficult to relate commercial pre-production activities directly to military Conceptual and Contract Definition Phase (CDP) activities. Commercial conceptual phase activities vary greatly with each program and can scarcely be related to each other; comparison with an AWACS-type approach is all but meaningless. This problem was compounded in the present study because the C-9A, C-9B and VC-9C programs more nearly reflected commercial practices than military. However, by making certain broad assumptions, a rough comparison to the more rigidized AWACS approach was possible for CDP-type activities.

Manufacturing activities, per se, do not reveal highly significant differences. Operations and Support activities vary from airline maintenance, through contractor support, to full organic support and are not directly comparable.

C-9A activities were related to those of AWACS by identifying the issuance of a Request for Quotation (RFQ) as comparable to the start of Contract Definition. A similar milestone for the commercial DC-9 program was the selection of a specific aircraft configuration for market exploitation. Program flows for these programs are included in Section III-B as Figures 9, 10, and 11.

C. REGULATORY CONTROLS/DATA ITEMS

The relative quantities of specifications, standards, regulations, procedures and data items on various commercial and military programs are shown in Tables 2 and 3. The category title "Commercial/Military Programs" signifies those unique C-9 military procurements that were structured more like commercial programs than military.

TABLE 2. REGULATORY CONTROLS

		SPECS/STDS/ETC
COMMERCIAL PROGRAMS		
	DC-8	36
	DC-9	43
	DC-10	42
COMMERCIAL/MILITARY PROGRAMS		
	C-9A	69
	C-9B	52
	VC-9C	52
MILITARY PROGRAMS		
	AWACS	261
	LRPA	303

The number of regulatory controls for Commercial and Commercial/Military Programs was obtained by counting the specific references to Civil Air Regulations, subcontractor specifications, military specifications, ARINC Characteristics, Douglas Specifications, etc., included in the Detail Specifications for the noted airplane types. The number of regulatory controls for the AWACS and Canadian Long Range Patrol Aircraft (LRPA) Programs, was obtained by counting the callouts in Paragraph 2.0, Applicable Documents, of each System Specification. Inasmuch as significant differences in the numbers of applicable controls were obtained by this simple process, no attempt was made to research any lower level expansion.

TABLE 3. ACQUISITION PHASE DATA ITEMS

COMMERCIAL PROGRAMS	
DC-8	25 (49 COPIES +)
DC-9	25 (49 COPIES +)
DC-10	30 (370 COPIES +)
COMMERCIAL/MILITARY PROGRAMS	
C-9A	37
C-9B	41
VC-9C	20
MILITARY PROGRAMS	
AWACS	222 (6100 COPIES +)
VS(X)	224

The number of contractual data items developed for commercial programs was obtained from contract exhibits or attachments on technical data and documents. The number of copies is the total number for all the items. That is, some items require only one copy while others require up to eight copies. The + indicates Service Bulletins and other documents which are supplied "as required" and are therefore difficult to quantify.

The number of contractual data items for the AWACS program was obtained from the Contract Data Requirement List (CDRL) of the AWACS Acquisition Phase RFP. The number of copies is approximate as the numbers of volumes per data item varied from 1 to 225 and the frequencies included one time, quarterly, month, and "as required". The product of all these combinations was, therefore, impossible to assess accurately. As in the case of the regulatory controls, significant differences in the numbers of applicable data items were obtained by this method and a more detailed count was not deemed necessary.

D. SUMMARY OF MANAGEMENT QUESTIONNAIRES

Since its creation, the Douglas Aircraft Company has been a major supplier of military systems and equipment and has participated in most major weapons systems programs involving commercial type aircraft. As a result of these many competitive exercises, there is a vast amount of knowledge and experience within the company in military and commercial procurement practices. Many management and experienced engineering personnel within the organization have been involved in both types of programs and have experience in the procedures and practices of program management and disciplines such as Engineering, Pricing, Material, Quality Assurance, Testing, Maintainability, Training, and Publications.

The opinions of these individuals, experienced in both military and commercial procurement practices, were solicited by widespread circulation of a questionnaire (Appendix D) designed to cover all disciplines. Forty-five responses were received. Those responding included 2 vice presidents, 11 directors and 32 managers or senior engineers. These responses, for the most part, reflect general attitudes, as opposed to statements of fact backed-up by specific documentation. It is believed that the attitudes of key management personnel regarding the real or imaged differences between commercial and military programs are highly significant in their approach to these programs.

Responses from experienced management personnel tend to confirm those problem areas highlighted in the findings and recommendations of studies reported in Section II-A, "Literature Search". These responses are summarized as follows:

1. General Comments

Excessive formal documentation created by absentee, multi-layered decision-making authority is considered a prime difference in most military programs when compared to commercial programs.

Wholesale application of procurement regulations, controls, MIL-SPECS and MIL-STDS, rather than careful selection of only those specifications and standards or the pertinent paragraphs within same which are directly applicable to the specific program, is considered an area where major improvement could occur. This recommendation directly impacts, and is considered contingent upon, vesting more decision-making authority at suitable levels.

There is universal agreement between management personnel that military procurement procedures are more cumbersome than those used on commercial programs. However, most believe the approaches to recent programs such as the F-16/F-17 and the AMST are improvements over the old procedures.

Another almost universal management opinion is that the military does not necessarily obtain a better quality product as the result of more controls, regulations, specifications and excess documentation. There is general agreement that use of "how-to" military specifications should be closely examined for specific program application before being imposed upon a military derivative program.

2. Specific Disciplines

a. Pricing:

One general comment regarding the pricing of military systems is that recording data in the format and quantity required for auditing purposes, including subcontractor data, requires considerably more effort (cost) than for commercial programs where the customer is concerned chiefly with the content, not the format, of data.

Commercial airplane warranties may vary considerably for reasons such as competitive pressures, past relationships between manufacturer and buyer,or operators maintenance capability. Commercial warranties may cover periods ranging from one year on equipment defects to several years on structural service life. Reputable suppliers are a must for successful warranty programs and an important consideration in the selection of suppliers for commercial programs is the warranties they are willing to give the manufacturer.

The standard warranty for a military airplane is a Correction of Deficiencies agreement whereby the manufacturer agrees to correct those deficiencies which become apparent during the first few months after delivery. The manufacturer acts as the sole interface with the government for the complete airplane, excepting government-furnished equipment. This procedure for military programs is in accordance with ASPR requirement. The reduced cost benefits of direct supplier warranties, as realized in commercial practice, are thus lessened by military procurement regulations on military programs. Warranty benefits to military programs are also reduced by the competitive, "low bidder" environment which constrains manufacturers and suppliers.

b. Material:

The general consensus is that parts and material procured to MIL-Specs are more expensive, and have higher rejection rates than equivalent commercial parts and material due to additional processing, testing or packaging specification requirements. For example, Douglas uses an 8 digit packaging code, while the MIL-SPEC code entails 72 digits. In addition to checking 11 charts to ensure that the correct code is used, it is necessary to provide considerably more nomenclature and dimensioning data for military parts packaging than for commercial programs. The time to prepare packaging instruction for a military part is 3-4 times as long as the time required for a similar commercial part.

c. Quality Assurance:

Comments agree that there is slight difference in the quality assurance program for military or commercial programs. A difference might be found in some additional documentation requirements in the initial phases of military programs, but this difference is considered to be negligible.

d. Testing:
A 10 percent increase in documentation and perhaps 20 percent duplication of total testing has been estimated for military aircraft programs. Some increase may be accounted for by peculiar subsystems but most is believed to be traceable to military regulatory requirements. Full scale environmental testing is much more severe for military systems despite the fact that commercial aircraft operate world-wide under essentially the same environmental conditions.

e. Maintainability:
Considerably more contractor effort is required (with attendant costs) to provide life-time support for a military aircraft system. Two major contributors for this difference are:

(1) Commercial operators cooperate on a world-wide basis by use of pooled maintenance facilities, ground support equipment (GSE) and spare parts while military organizations require self-sufficiency to support unscheduled operations. The practice of Prime Contractor Procurement places the burden of selection or design, and procurement, of the entire support system on the contractor.

(2) There is no overall solution which would substantially reduce the spares stockpile costs for military systems and still support military operational requirements. However, contractor support for programs like the C-9A, C-9B, and VC-9C appears to be a good solution for systems which operate largely in non-tactical roles. As discussed in paragraph III F-1, the C-9 contractor support concept is for military personnel to "remove and replace" while the contractor provides on-site spares supply. Five year savings of approximately 45 percent have been realized on the C-9A program when compared to full organic support. This concept may be extended to certain tactical systems if solutions to problems such as civilian labor walkouts can be found.

Lifetime spare parts support for the military is complicated when the procurement contract ends and the production line shuts down. Lifetime spares support for commercial operators are generally available for a much longer life production line.

f. Training:

There are obvious differences in training requirements for military operational and support personnel created mostly by assignment practice and longevity. Both commercial and military organizations utilize simulation and ground training devices designed on a cooperative basis to meet training requirements. The military and commercial training departments at Douglas constantly exchange ideas and information for the mutual benefit of programs in both areas. Military maintenance training requirements tend to be more basic and to require more effort and time than those for the advanced experience level of commercial maintenance personnel.

g. Publications:

The preparation of Technical Manuals and related data in accordance with MIL-SPECS is considerably more time consuming and expensive than for their commercial counterparts and this expense is magnified by differing requirements for other services. The Navy is converting to microfilm, versus hard copy; however this may not prove completely satisfactory for either the Air Force or the Army on the premise that reader/printers appear to have a high failure rate and, as facetiously stated, "It may be difficult to find a microfilm reader in the jungle". Military publications contain more detail than that required for commercial publications, due largely to the experience level of using personnel. While not universally factual, a new military aircraft system may represent a greater jump in complexity for the operational organization because the military tends to retain old equipment for longer periods than commercial operators do.

E. COMPARISON METHODOLOGY AND RATIONALE

AWACS and the C-9A were modification programs, each based on a mature commercial aircraft. The DC-8 had been flying in commercial revenue service for 9½ years at the time of AWACS Contract Definition and the DC-9 had been in operation for 1¼ years when the C-9A derivative was formally proposed to the Air Force.

To compare these military modification programs, similar commercial developments had to be defined. Percent of change of cost weight is the parameter most often used to compare modifications and is defined as a percentage of the cost weight of the original model; similarly, engineering-hours for modification design and test are compared to those expended on Ship One. For this report, cost weight is defined as Manufacturers Empty Weight less engines, tires, wheels and brakes (similar to DCPR weight used by the military).

As shown in Table 4, the DC-9-61 and the AWACS air vehicle cost weight changes equal 28 percent and 26 percent, respectively, of the original DC-8 cost weight and a similarity between these two derivatives is suggested. However, the 8 percent change in engineering hours for the -61 is in sharp contrast to the 47 percent change for AWACS.

TABLE 4. COMPARISON OF DEVELOPMENTS

		PERCENT CHANGE FROM SHIP 1			
MODIFICATION	CHANGE	COST WT	ENG HOURS	LAB TEST	FLT TEST
DC-8-61	37 FT STRETCH	$\boxed{28}$	8	6	23
-62	NACELLE, PYLON, 7 FT STRETCH	33	14	9	34
-63	-61 + -62	7	2	3	16
-61F	CARGO SYS & DOOR	10	0.2	—	—
AWACS	SYSTEMS, ENGINE, GROSS WEIGHT	$\boxed{26}$	47	142	114
DC-9-21		1		—	5
-31	ENGINE, LIFT SYSTEM, 15 FT STRETCH, FUEL	$\boxed{33}$	16	28	23
-41	ENGINE, -31 LIFT SYSTEM, 21 FT STRETCH	11		—	6
C-9A	RAMP, SYSTEMS, INTERIOR	$\boxed{17}$	8	5	3

The -61 commercial modification was a relatively simple fuselage stretch and the lab test hours reflect this. However, the -61 flight test hours reflect the program involved in this long stretch version of the DC-8. Similarly, the greater complexity of the AWACS air vehicle modification is obvious in the very large lab and flight test hours change. Whether the engineering and test hours are proportionate to the complexity is examined in Section III.

Table 4 also shows that the DC-9-31 cost weight change is twice that of the C-9A, but so is the change in engineering-hours, so a comparison may be made, keeping in mind this 2:1 factor. The relatively high lab and flight test hours change for the -31 reflects the nature of the engine, lift system and structural changes. Similarly, the C-9A test hours change reflects only some laboratory work on the integral loading ramp and little flight test, as the external configuration was not altered.

To compare the DC-8-61 modification program with AWACS on an equitable basis, the air vehicle modification portion of AWACS had to be separated from the rotodome and mission-avionics development. Fortunately, the Work Breakdown Structure collected rotodome, mission systems and avionics integration costs separately from those involving the basic air vehicle, Figure 2. The WBS also identified separate functions for design of the basic air vehicle, the interior configuration, avionics, as well as the functions of administration and system test. The WBS for other system/program elements permitted those AWACS-peculiar items such as the ground entry system, computer programs, etc., to be separated.

Seventy-two percent of the air vehicle group design effort was charged directly to the air vehicle, with the other 28 percent being spent on the mission-peculiar elements. The sub-total for the support group was therefore multiplied by 72 percent to obtain the total number of hours charged directly to air-vehicle design. Similarly, the totals were obtained for the other functional elements and summed-up to provide the total design engineering and test hours directly attributable to the air vehicle.

WBS ELEMENT	AIR VEHICLE		CONFIG		AVIONICS	SYS ENGG	ADM	SYS TEST	
	DES	ANALYSIS	DES	SUP				LAB	FLT
AIR VEHICLE	72%	92%	59%	40%	4%	—	94%	49%	51%
~~ROTODOME~~	~~4%~~	~~8%~~		—	~~3%~~		~~1%~~		
~~MISSION SYSTEM~~	~~6%~~			~~1%~~	~~71%~~	~~97%~~	~~4%~~		
~~AVIONICS INSTEG~~	~~18%~~	—	~~41%~~	~~59%~~	~~22%~~	~~3%~~	~~1%~~		
SUBTOTALS									
SYSTEM TEST								—	—
SYS/PROJ MGMT									
DATA									
TRAINING									
PECULIAR SUPP EQ									
COMMON SUPP EQ									
SYS REFURB									
~~GRD ENTRY SYST~~									
~~COMPUTER PROG~~									
~~BRASS BOARD~~									
~~SYSTEM DEMO~~									
SUBTOTALS	X72%	X92%	X59%	X40%	X4%	X 47%	X 94%	X49%	X51%
TOTALS									
	TOTAL ENGG HOURS FOR AIR VEHICLE							TOTAL TEST HOURS	

Figure 2. AWACS WBS Breakdown

To provide a means of relating design complexities of different modifications, a frame of reference was established, based on Ship One of each model line. In Table 5, the major elements of the aircraft are compared on the basis of design hours per pound of cost weight, with the value for fuselage structure being defined as unity. It can be seen that the design hours per pound of flight controls, power plant, environmental and electrical components are very large when compared to those required for fuselage structure; the design cost for a pound of electrical cost weight is almost 10 times that for a pound of fuselage structure.

TABLE 5. DC-8 SHIP ONE DESIGN COMPLEXITY

	HR/LB COST WT		GROSS COST WEIGHT		EQUIV COST WEIGHT
FUSELAGE STRUCTURE	1	X	17.871	=	17.871
DOOR STRUCTURE	1.465		4.638		6.795
TAIL STRUCTURE	1.233		13.183		16.254
WING STRUCTURE	0.629		30.169		18.976
INTERIORS	2.081		6.683		13.907
HYDRAULICS	2.176		5.444		11.846
CONTROLS	5.076		1.850		9.391
POWER PLANT	4.246		7.723		32.792
ENVIRONMENTAL	7.221		3.865		27.909
ELECTRICAL	9.899		4.054		44.585
			95.930		200.326

TOTAL DESIGN COMPLEXITY (RELATIVE TO FUSELAGE STRUCTURE)

$$= \frac{200.326}{95.930} = 2.09$$

The actual cost weights are multiplied by the hours-per-pound ratios to provide equivalent cost weights. For DC-8 Ship One, the overall number of man-hours to design the 95,930 pounds of combined cost weight is the same as that which would be required to design 200,326 pounds of fuselage structure. Therefore, the design complexity for the total aircraft is the quotient of 200,326 divided by 95,930 or 2.09. This number is a measure of the design requirements imposed by Douglas' first commercial swept-wing jet aircraft with its expanded operational envelope and large size.

Using the procedure previously described to determine the overall complexity of Ship One, the complexities of various modifications were established. These were then divided by the value for Ship One to provide relative complexities for each modification, Table 6.

TABLE 6. RELATIVE COMPLEXITIES

DEVELOPMENT	EQUIV COST WEIGHT / ACTUAL COST WEIGHT	COMPLEXITY FACTOR
DC-8-SHIP 1	2.09	1
-61	2.06	0.98
-62	2.21	1.07
-63	1.27	0.69
-61F	1.29	0.59
-62F	1.52	0.52
-63F	1.19	0.50
-AWACS	3.01	1.47
DC-9-SHIP 1	1.30	1
-21	0.71	0.55
-31	1.03	0.80
-41	1.14	0.88
C-9A	1.53	1.18

The DC-8-61 modification was approximately equal in complexity to the basic DC-8 design effort, while the -62 with its emphasis on high cost nacelle and pylon design was slightly more complex. The -63 which combined the -61 stretch and the -62 nacelle/pylon, was less complex than the basic design, as were the relatively simple freighter versions. The AWACS, with its costly system changes, new power plants and interior changes, resulted in a considerably higher complexity factor.

DC-9 Ship One had a complexity factor of 1.30; several years of modern jet transport design experience are reflected in this number compared to the 2.09 complexity factor for the initial DC-8. The T-tail configuration of the DC-9, along with its aft-mounted engines, contributed to the overall complexity ratio. The DC-9-31 changes were all well within the state-of-the-art, and therefore resulted in a lower complexity ratio than for the original airplane. However, the new integral loading ramp and high cost systems and interiors changes for the C-9A produced a somewhat higher complexity factor.

The standard planning curve, Figure 3, is based on historical data from various development programs and is used by engineering estimators for preliminary evaluation of modification programs. The upper right corner represents

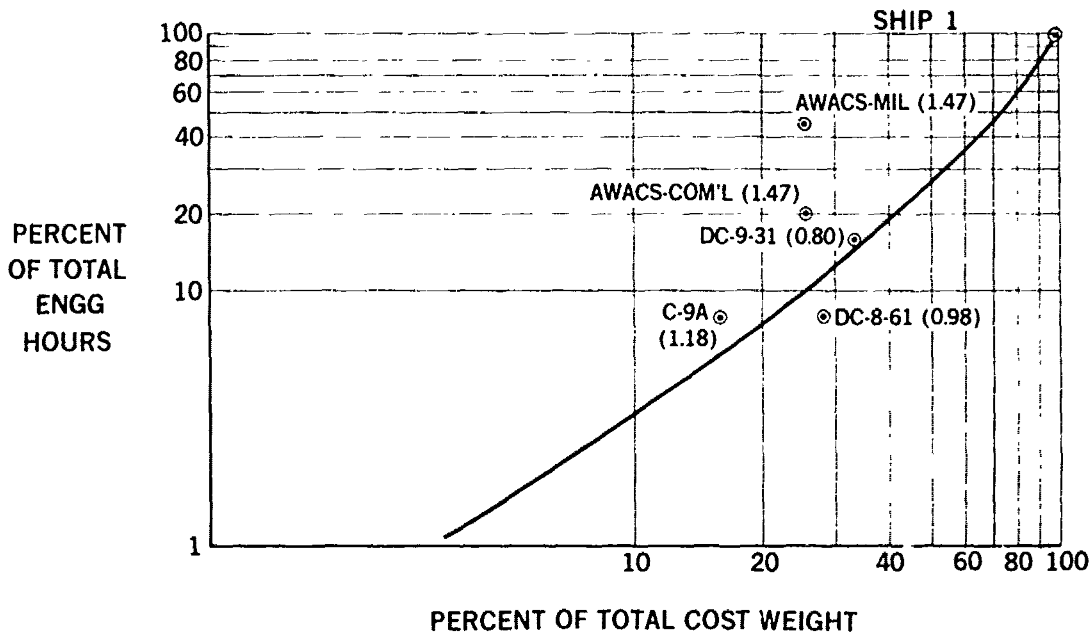


Figure 3. Standard Planning Curve

the total effort for Ship One of the model line. Modifications with complexity factors equal to that for Ship One should fall approximately on the line, with allowances made for perturbations which may affect specific programs. The DC-9-31, which experienced a mid-course redirection with attendant increased hours, reflects such a perturbation.

The C-9A point falls slightly above the line as expected. The DC-8-61, -62, -61F, and -63 points all fall approximately as expected. However, the AWACS point, based on the formal bid, falls well above the line. Estimating the AWACS by commercial methods, brings the point down to a location, which for its relatively high 1.47 complexity factor, might be considered appropriate for a commercial modficiation. The large difference in percent of total hours (47 versus 20) indicates the involvement of vastly different factors in the two estimates. The quantity and depth of regulatory controls and data items, and the generation of aerodynamic and stress data not required for the commercial program are examples of these differences.

SECTION III

COMPARISON AND EVALUATION OF MILITARY AND COMMERCIAL PRACTICES

Drawing on the data base generated per Task I, military and commercial practices were compared and analyzed in Task II to define major differences during the various program phases from Initial Planning to Operations and Support; while the magnitude and causes of these differences were the subjects of Task III. Because the definition and qualification of differences are so closely related, the results of these two tasks are combined in this section.

Due to the nature of the study, the impression might be given that military practices are generally not as good as commercial practices. However, it should be remembered that only major differences favoring commercial practices are being described and no overall criticism of the military process is intended.

A. PROGRAM MANAGEMENT

Five major aspects of Program Management on military and commercial programs are discussed in terms of signficant differences:

- Responsibilities and Roles
- Development and Implementation
- Contractual Program Data
- Government Program Personnel
- Configuration Management

1. Responsibilities and Roles

The primary management roles on military and commercial programs are shown in Table 7. The purpose of this table is to illustrate the almost complete role reversal between the contractor and the customer on the two types of programs, and the consequences of this reversal. While variations occur in varying degrees on specific programs, the fundamental relationship at the interface remains essentially intact.

TABLE 7. PRIMARY MANAGEMENT ROLES

	COMMERCIAL		MILITARY	
	CONTRACTOR	CUSTOMER	CONTRACTOR	CUSTOMER
PRE-CONCEPTUAL				
REQTS DEFINITION	✓ OR	✓		✓
INITIAL SOLUTIONS	✓ OR	✓		✓
PREL PROGRAM APPROACH	✓			✓
CONDITIONAL GO-AHEAD	✓			✓
CONCEPTUAL				
REQUIREMENTS DEVELOPMENT	✓			✓
SELECTED SOLUTION	✓			✓
SELECTED PROG APPROACH	✓			✓
VALIDATION				
INITIATION OF CONTRACT ACTIONS	✓			✓
DECISION TO PARTICIPATE		✓	✓	
DETAIL DESIGN	✓		✓	
BASIC DELIVERY SCHEDULE	✓			✓
MANAGEMENT APPROACH	✓			✓
PRODUCTION GO-AHEAD	✓			✓

Commercial developments are generally evolutionary in nature, building on current systems and concepts and offering economic improvements to the customers. The contractors constantly search for ways to improve their customer's services by upgrading or adding to their own product lines. They initiate new concepts and actively promote them to their customers. Of course, in some cases, this activity may be initiated by a customer, as in the case of the DC-10. However, even in this case, after a period of coordination with the initiator and other potential customers, Douglas effected a compromise approach and led the subsequent efforts. Therefore, on a commercial program the contractor assumes the principal role at or near the outset, and is the overall prime party as regards development of the concept. While continuing inputs from the airline customers are of major significance, the contractor maintains management control of his program, promotes it as he deems necessary and makes the final decision to go-ahead or to terminate the effort based on cost of production, anticipated sales, etc. His efforts are concentrated almost wholly on those items which he needs to influence the potential customers and to satisfy his own internal management.

On the other hand, military programs may be revolutionary as well as evolutionary, in nature. On military programs, the appropriate service, often because of classified or operational necessity, assumes prime responsibility for developing and establishing the programs. This includes identifying and defining the need and requirements for the new system, for describing one or more acceptable systems and attendant development programs and for authorization of a go-ahead for further study. Contractors may support, or actually prompt, these activities, usually on an unfunded basis, but the prime role is always assumed by the military. Similarly, responsibility for further development of the concept and the suggested program remains with the military, supported by the contractors through funded Conceptual Phase studies.

When the appropriate levels of military and government management are satisfied that the program is justifiable and viable, contractors are invited to compete, as prime contractors, for funded Validation Phase studies to provide detailed analysis and design of the selected system, including the air vehicle, a complete integrated support system, the required operational facilities, the total manpower and training requirements. However, even though the expression "prime contractor" seems to imply a transfer of responsibility for the program development, in reality this does not occur. The basic go-ahead decisions are all controlled by the military. The contractor, therefore, must react to military management direction, often investing a great deal of his own money in areas that he might not pursue as deeply or at all on a comparable commercial program. These areas include special cost, performance, manufacturing and testing planning and reporting procedures, MIL-Spec structural integrity demonstration, detailed configuration management, etc.

During the competitive phases of a military program, the SPO may not be available for questions from contractors; if it is, the questions and answers are provided to all competitors. Many proprietary ideas which could greatly benefit the system, are therefore withheld, and perhaps lost, when the contract award goes to another competitor. This is not the case in the commercial field where competition lasts long after initial selection. The result is that the customer is always aware of the latest concepts and may act accordingly.

Figure 4 illustrates the difference in military and commercial responsibilities. On a commercial program, the contractor's primary responsibility is focused on the air vehicle. The airline operators themselves assume the primary responsibility for developing the operations and support elements of the system, areas in which they have established the expertise necessary to operate safely and profitably. The airlines are, of course, supported in their efforts by the contractor. However, on a major military program, the contractor is requested to assume responsibility not only for the air vehicle portion, but also for definition of the complete integrated logistics program, the required operational facilities, plus total manpower and training, as required by the contract, during all phases of system life cycle.

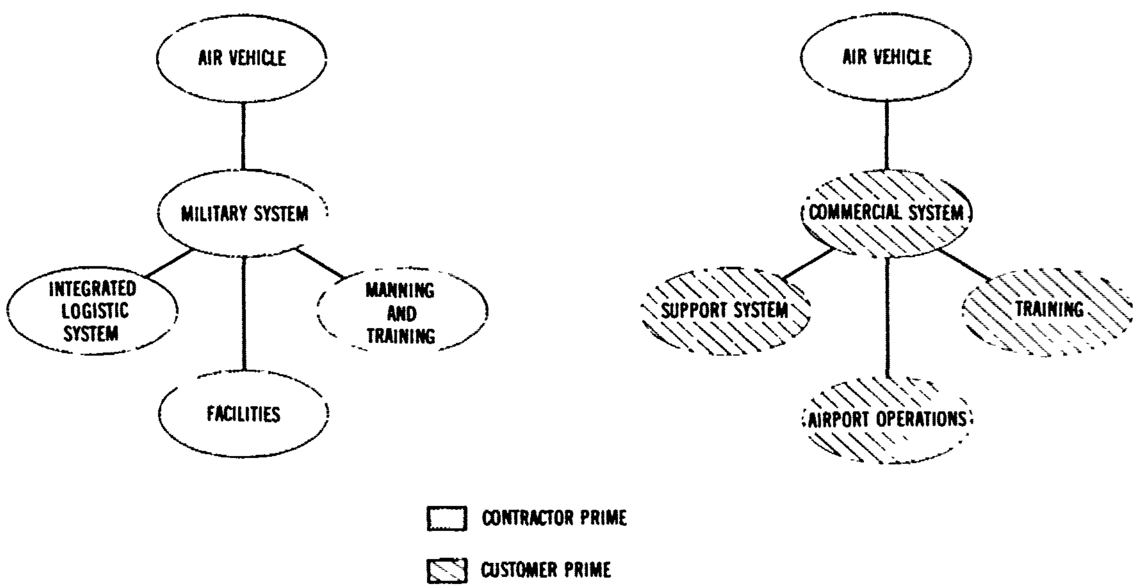


Figure 4. Contractual Responsibilities

For the commercial contractor who wants to bid on a military derivative of his aircraft, this variance in responsibilities has a significant impact. He must expand his management, control, analysis, and data functions, in almost all areas, beyond the strength required for commercial programs, to provide much more in-depth data covering a broader scope. This expansion starts very early in a military program, grows to a peak during the preparation of the Acquisition Phase proposal and is sustained during pre-ATP evaluation. Should he not win the award, the expansion manpower must be released, with considerable attendant expense.

2. Requirements Development and Implementation

Another significant difference between military and commercial management practices concerns the process involved in the development and initiation of system requirements. As noted previously, this is usually a military function on military programs and a contractor or shared function on commercial programs. Beyond this basic difference, however, lies a much more meaningful difference, that of the assignment of responsibility.

The initial military requirement is typically generated by a using command and developed by a staff agency until it becomes a line item on the service budget. Conceptual Phase studies are then directed by a Project Officer. After DSARC I, a Program Manager is named and charged with implementing the program. This person usually has had little or nothing to do with the generation of either the technical requirements, budget, schedule, or program approach. His authority is often diffused among technical agencies, procurement boards and audit agencies. During the course of the program, several turnovers may occur in this position as officers are rotated. Other key management personnel are similarly assigned and rotated.

On a major commercial program, the Program Manager and other key management personnel are assigned much earlier than their military counterparts. They have program experience in their specific fields and remain on the program through major program phases. The Program Manager has direct control of the technical approach, prices, program functions, and schedules. His lines of communication with company management are short and direct and the authority is clear and adequate. Thus, the commercial program manager has the power and the means to manage more effectively and efficiently than his military counterpart.

3. Contractual Data

A summation of Acquisition Phase Data Items for military and commercial programs was developed as part of the data base, Table 3. An order of magnitude growth was observed between the number of CDRL line items for AWACS and comparable types of data items supplied to commercial customers. A modest growth in data items was observed between the commercial DC-9 programs and the military C-9 commercial-type programs.

There is an important difference between the two types of programs. Military practice is to require the contractor to regenerate his original data, plus new items in specific military formats - so that their own agencies can oversee the development and determine the airworthiness and safety of the airplane. The commercial customer, however, is buying an airplane already certified as airworthy by the FAA, so he is not as concerned with the detailed analyses and tests which were performed during development.

On the AWACS program, the Acquisition Phase CDRL listed 208 data items in 13 different categories, Table 8. Many of these data items had very large

TABLE 8. COMPARISON OF DATA ITEM CATEGORIES

CATEGORY	AWACS	AIRLINE (DC-8/DC-9)	FAA (DC-9)
ADMIN AND FINAN	8		
CONFIG MGMT	31	1	
ENGG DATA SUP	12	4	
FACILITIES	1		
HANDBOOKS	15	9	2
LOGISTICS	11	1	1
MGMT/PERT	9		
PROC AND PROD	4		
PERS SUBSYS	22		
REL AND MAINT	13	1	18
SYS/SUBSYS ANALYSIS	42		76
TEST	12	9	125
MISC	29		
TOTAL	208 (+87 CDP)	25	222

distributions (e.g., Category I Test Plan/Procedures, 52 copies; System General Specification, 64 copies; Biomedical Problems Data, 27 copies; Preliminary Technical Publications, 225 copies) and were updated "as required".

In comparison, there were 25 data items in 6 categories contractually prepared for each commercial DC-8 and DC-9 airplane. The number of copies submitted for each aircraft was small (e.g., Aircraft Packing Sheet, 8 copies; Actual versus Guaranteed Weight Report, 4 copies; Airplane Flight Manual, 1 copy; Maintenance Manual, 1 copy) and there are no specified updating requirements.

However, to make a valid comparison with the AWACS data items, the documentation required by the FAA for issuance of Type and Production Certificates must be included. For the DC-9, figures were available that show a total of 222 copies of data items in 5 categories were submitted; but many of these were memo reports consisting of relatively few pages. Of particular interest are the areas of concern - over 90 percent of the documentation dealt with Testing and System and Subsystem Analysis. Of equal interest are the areas for which neither the airlines nor the FAA require documentation, such as Management, Production and Personnel Subsystems. On new military airplane developments these categories of data are obviously necessary. However, on derivative programs, where the airplane has been proven in commercial service, regenerating old reports and creating new ones is costly and hard to justify.

A highly significant cost factor in the consideration of contractual documentation is the number of pieces of paper generated for every piece of paper submitted. Figure 5 shows the actual accounting of documentation developed by Douglas during AWACS Contract Definition.

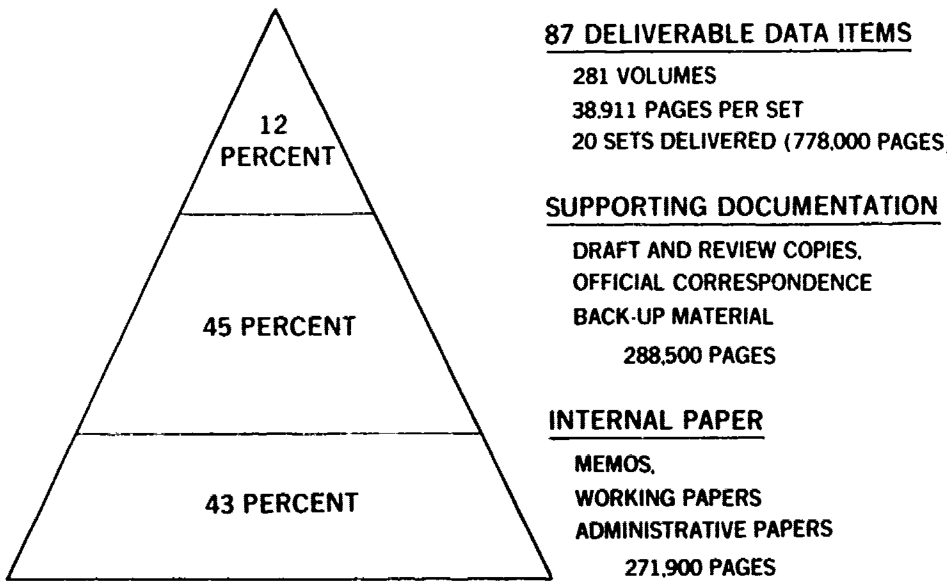


Figure 5. AWACS CDP Documentation

The AWACS CDP study product comprised approximately 39,000 pages per set of 281 volumes - and 20 sets totaling 780,000 pages were submitted. This compares with 90,000 pages per set of 787 volumes - and a submittal of 30 sets totaling 2,700,000 pages for the C-5A.

The 39,000 pages of AWACS data amounted to only 12 percent of the total paper generated for the submittal. The other 88 percent of the paper generated comprised supporting documentation and other internal paper. A large staff was maintained just to handle this volume of paper. The significance of these numbers is that in addition to the cost for each page of data submitted, there was an additional cost for generating and handling nine other pages of data which were not submitted.

Every page that can be eliminated from a formal submittal will save the cost of that page, plus nine other pages of non-deliverable, backup paper.

The development of data involves three functions; preparation, production, and reproduction: preparation includes authorship, draft typing and review; production includes final typing, editing, correction and book make-up; reproduction includes printing, collation and binding. The cost of authorship and review for the AWACS final submittal is estimated to have been approximately $621,000. The cost of draft and final typing, editing, book make-up, printing, etc., is estimated to have been approximately $446,000. The manpower required just for this support effort is shown in Figure 6.

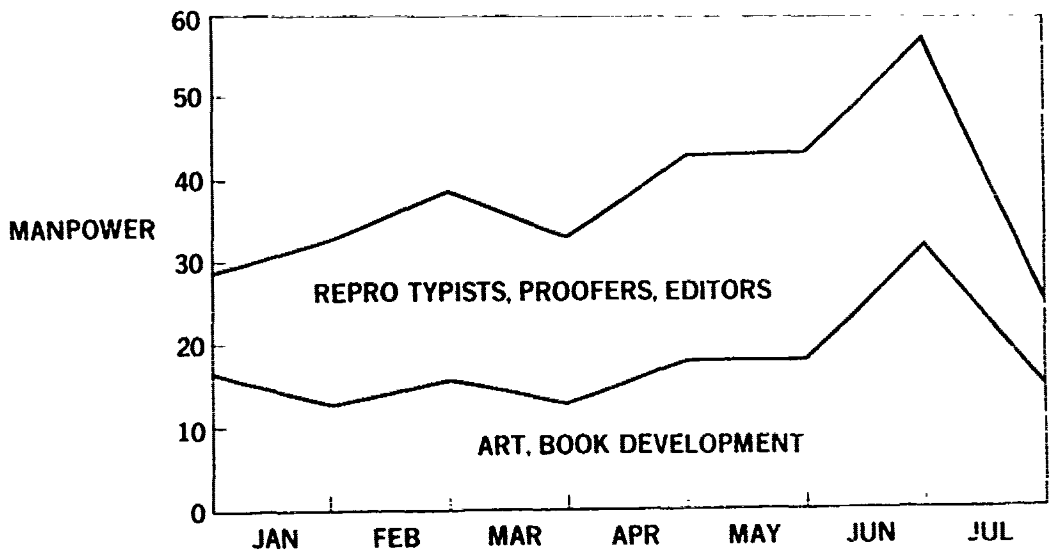


Figure 6. AWACS CDP Documentation Support Effort

The total sum of $1,067,000 was equivalent to $27.42 per page at the hourly rates prevailing in 1969. If the 560,000 pages of supporting and internal documentation were developed at only 10 percent of this rate, their cost would have added another $1,530,000 to the total documentation cost.

It is important to remember that for every piece of deliverable paper, approximately 9 other pieces of paper are generated and handled. This effectively doubles the cost of the deliverable paper.

4. Government Personnel

The number of government personnel assigned to, or in support of, the System Program Office (SPO) has differed greatly on recent programs, Table 9. The AWACS SPO numbered 30 people at the time of the third review during CDP; this number did not include an additional 10 people who were directly concerned with the mission system. Another 136 people for ASD, the operating commands and various other agencies brought the total of government people involved with the air vehicle and the program function to 166. The total number of government people, including those concerned with the mission system, was 317.

TABLE 9. GOVERNMENT PERSONNEL

	C-9A (C-141/C-130)	VC-9C (T-43)	AWACS *
SPO	8	5	30
ASD ENGG	13	2	42
NAVPRO	5	6	—
FAA	2	6	—
AFLC	16	8	—
OPERATOR	20 (MAC)	6 (89 MAW)	29 (TAC. ADC)
USAF	2	1	—
AFSC	1	1	—
MISC	—	—	65
	57	35	166

* LESS MISSION SYSTEM PERSONNEL

The USAF C-9A Nightingale aeromedical aircraft was the first of the military DC-9 family. The C-9A SPO is a part of the C-141/C-130 SPO which numbered a maximum of 8 people at the height of the program. They were supported by 45 other people in various agencies. Similarly, the VC-9C Executive Transport SPO is a part of the T-43 SPO and [illegible]d a maximum of 5 people, supported by 30 others.

The Air Force and the Navy each agreed to handle their C-9 procurement in accordance with commercial configuration change practice. This permitted the contractor to use his normal business practices and thereby avoid the extra, non-productive expense of creating comparable, but different, paperwork.

Of particular interest is the utilization of the resident Naval Plant

Representative Office (NAVPRO) and the local FAA Office on the C-9 programs, Table 10. The NAVPRO functioned as an arm of the SPO for day-to-day program functions; the FAA functioned in the specific areas of airworthiness, test and certification. The proper use of these available, local government agencies avoided the need for long range, formal documentation and the delays inherent in such a practice.

TABLE 10. GOVERNMENT ROLES ON C-9 PROGRAMS

NAVPRO	FAA
• ENGG SUPPORT MONITOR DES AND DEV EVAL TEST PROCED. VALIDATE SCN'S SUPPORT SPO REVIEWS	• ENGG SUPPORT ASSIST IN AIRWORTHINESS TEST DEV. SUPPORT USAF INSP. ISSUE CERTIF OF CONFORMITY. MINIMIZE EXCEPTIONS
• QUAL ASSURANCE REVIEW USAF-PECUL ITEMS MONITOR FAB PROC. MANAGE T.O. PRINTING	• QUAL ASSURANCE INSPECT CHANGES (DMIR) ISSUE PROD CERTIF.
• PRODUCTION PROD. SURVEILL GFAE/GFP/AGE CONTROL LOGISTICS REVIEWS DATA MGMT	
• CONTRACT ADMINISTRATION COORDINATE PROG. PAYMENTS. NEGOTIATE CHANGES UP TO $500 K. NEGOTIATE GFP REPAIR TO $5 K	
• FLIGHT OPNS ACCEPTANCE PREP. FLTS. INSP AND ACCEPT.	• FLT OPNS CERTIFICATION FLIGHTS.

An additional saving in government manpower results when the FAA designee system is used. In accordance with the Federal Aviation Act of 1958, the FAA promulgated Part 183, Subchapter K, of the Code of Federal Regulation. This document describes the requirements for designating private persons to act as representatives of the Administrator in examining, inspecting and testing persons and aircraft for the purpose of issuing airman and aircraft certificates. In addition, it states the privileges of those representatives and prescribes rules for their exercising of those privileges. In addition to designees for operational functions such as pilot and medical examiners, designees are named for engineering and manufacturing functions, Table 11. In many cases, these people are contractor employes filling a dual role. They work out procedures and plans with their FAA counterparts, direct the efforts and certify the results. The keys to this relationship are faith in the contractor by the FAA and the maintenance of a high level of integrity on the part of the designees. The successful implementation of the designee practice has enabled the FAA to perform its function without maintaining large numbers of people to handle major commercial developments. The excellent safety record of the commercial aerospace industry is proof of the effective workability of this practice.

TABLE 11. FAA DESIGNATED REPRESENTATIVES

DESIGNATED ENGINEERING REPRESENTATIVES (DERs)

- STRUCTURAL
- POWER PLANT
- SYSTEMS AND EQUIPMENT
- RADIO
- ENGINE
- PROPELLER
- FLIGHT ANALYST
- FLIGHT TEST PILOT

DESIGNED MANUFACTURING INSPECTION REPRESENTATIVES (DMIRs)

- INSPECT AS NECESSARY
- ISSUE
    - ORIGINAL AIRWORTHINESS CERTIFICATES
    - EXPORT CERTIFICATES OF AIRWORTHINESS
    - EXPORT FERRY CERTIFICATES
    - EXPERIMENTAL CERTIFICATES

5. Configuration Management

The cost of configuration management for the AWACS and C-9 programs varied greatly because of the approach to specifications. AWACS required a formal MIL-STD approach to specification development and control while the C-9 programs followed a commercial specification approach.

The controlled portion of the AWACS specification tree dealing with the air vehicle and its interfaces was comprised of individual Contract End Item specifications for the System, the Mission System and Interface Segment, the Air Vehicle Functional Group, and the Air Vehicle, Engine and Rotodome, plus the Communication, Navigation, A.G.E., Mobile Training Unit, and Facilities Functional Groups, Figure 7. Numerous other lower level specifications were not to be submitted to the SPO, but were to be available for examination upon request. These "visibility" specifications were subject to the same configuration management procedures as the others. The total number of AWACS specifications developed during CDP was 119, comprising 7,789 pages.

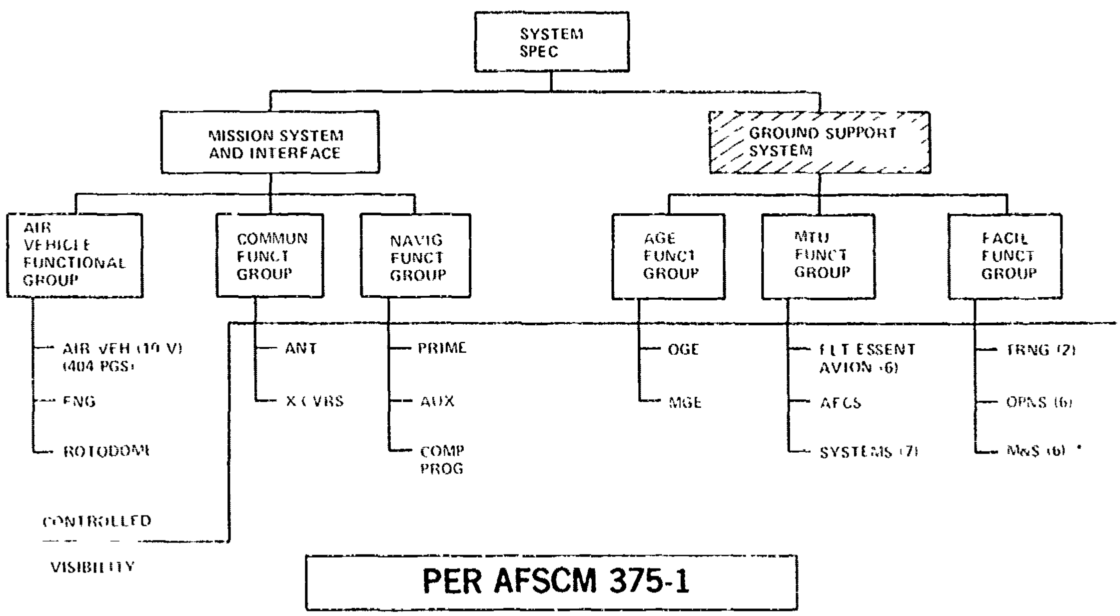


Figure 7. AWACS Air Vehicle/Interface Specification Tree

The two functions of configuration management during an Acquisition Phase are called "Identification" and "Configuration Control and Accounting". These functions pick-up the requirements specifications developed during Contract Definition, control changes which are directed during technical transfusion and manage the development of the "build-to" specifications during Acquisition.

The configuration management plan for the AWACS Acquisition Phase was 102 pages long. It stated that 15 people would have been required to handle the initial volume of requirements specifications prepared during Contract Definition, Figure 8. With a decrease in the volume of paperwork as the

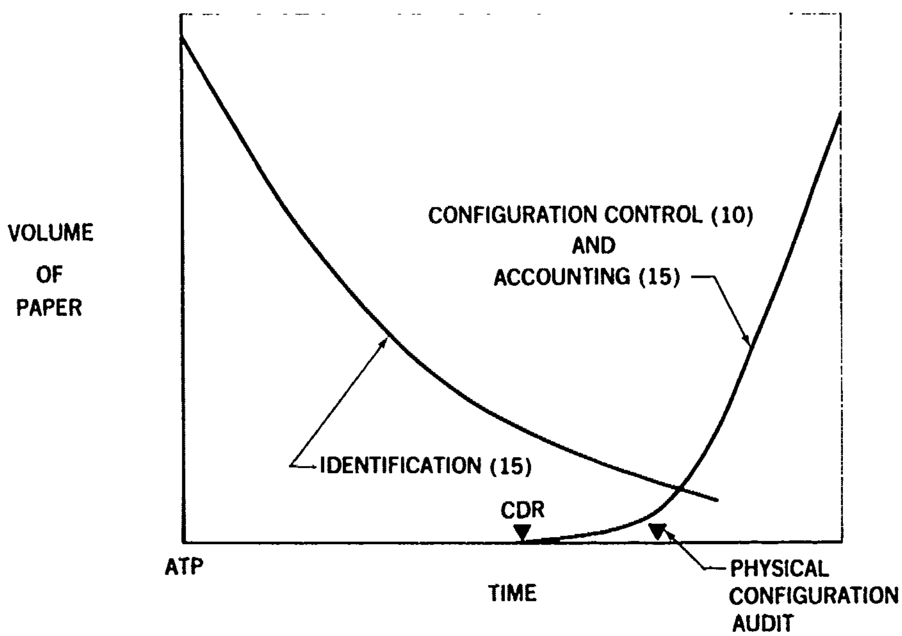
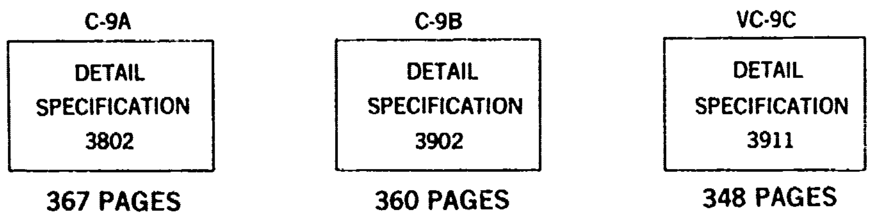


Figure 8. AWACS Configuration Management Estimate

requirement specification changes were documented and the "design-to" specifications were completed, the manpower requirements would also decrease. The other functions of configuration management, Configuration Control and Acounting, initiated for the Preliminary Design Review, would have started to build-up at the time of the Critical Design Review (CDR) and the build-up would have accelerated significantly following the Physical Configuration Audit, formerly called First Article Configuration Inspection (FACI). Manpower requirements for the Control and Accounting function would have peaked at twenty-five people.

The cost of the configuration management activity during the 47-months of AWACS RDT&E would have been more than $3,900,000.

The C-9 programs were handled as configuration changes to the basic aircraft and standard commercial procedures were used. The DC-9-32 specification was modified for each application and the resultant specification served as the contractual basis for each procurement, Figure 9.



- DEVELOPED FROM COMMERCIAL SPECIFICATION
- VENDOR ITEM SPECIFICATIONS IN COMMERICAL FORMAT, WHEN SUBMITTED

Figure 9. C-9 Program Specification Trees

Configuration Management on the C-9A program involved one full-time person, supported by the equivalent of another half-time person. The cost of these one and one-half people performing configuration management duties during the 27 months from the initial USAF Request for Quotation until the first delivery was approximately $134,390. After the C-9A became operational, the configuration management manpower dropped to approximately one-half an equivalent man. The development of the C-9B and VC-9C aircraft was handled by the same part-time people. Additions and changes to the commercial content were reviewed by the local FAA and either approved or noted as exceptions to the DC-9-32 Certificate of Conformity. These exceptions generally consisted of those items unique to the military mission and not normally installed on commercial aircraft. Changes to the baseline specification included standard product improvements and ECP-type changes. Standard improvements were incorporated on a running basis in accordance with commercial practice. ECP's were accomplished per MIL-STD-480, but treated internally as commercial changes.

6. AMST Program Management

The current USAF Advanced Medium STOL Transport (AMST) Prototype Program offers an innovative, effective approach to military development and production programs.

A special study group was established by the Air Force a few years ago to develop guidelines for a streamlined, low-cost approach to systems prototyping. The results of this effort generally suggested relaxation of government controls and involvement. Utilization of contractor's management and procurement practices to a much greater extent was recommended to avoid the expense of implementing specific government practices. Similarly, reductions in documentation and reporting requirements were suggested and, again, emphasis was placed on contractor in-place procedures.

The replacement of formal specification requirements by design goals was proposed to encourage the contractor to be more imaginative - a highly desirable factor in prototyping. System performance measurement against the design goals instead of against the more rigid specifications likewise was suggested to broaden the latitude available to the contractor and to permit more effective utilization of his resources.

The current AMST prototype is one of the first major systems to be developed under the new guidelines; this program is intended to develop the basic technology for a STOL production program. Two competing contractors are currently developing prototype aircraft. These aircraft, representing two different technology approaches, will be flown to define and evaluate operational and cost criteria. It is intended that the configuration for a production aircraft be the outgrowth of the prototype program.

The AMST RFP contained several features not normally found in an RFP for a system development program, Table 12. The funding ceiling and future production cost targets were specified; however, tradeoffs of performance reduction to stay within the cost ceiling, as well as added costs to achieve higher performance, were also requested. The RFP contained no design MIL-SPECS. The entire RFP was 48 pages long; the Statement of Work was one page long and Design Requirements and Goals was about one and one-quarter pages long.

TABLE 12. AMST PROTOTYPE DEVELOPMENT RFP

RFP FEATURES

- FUNDING CEILING
- FUTURE PRODUCTION COST TARGET
- DESIRED TRADEOFFS
  - PERFORMANCE REDUCTIONS VS COST
  - ALTERNATIVE COSTS VS PERFORMANCE GOALS
- NO DESIGN MIL-SPECS
- 48 PAGES TOTAL

MODEL CONTRACT	35
PROPOSAL INSTRUCTIONS	2
EVALUATION CRITERIA	2
SOW	1
COST/PERFORMANCE/DESIGN GOALS	2
TRANS. LTR, AMENDMENTS, ETC	6

- 75 PAGE PROPOSAL LIMITATION

TECHNICAL INFORMATION	50
TRADEOFF ANALYSIS	15
MANAGEMENT DATA	10

The YC-15 made its initial flight approximately eight months ahead of schedule. The innovations in design and production made possible by the nature of the procurement contributed materially to this accomplishment. Additional discussions of specific YC-15 practices may be found in Sections III C-3 and III D-3.

B. INITIAL PLANNING

For the purposes of this study, Initial Planning activities are defined as those events which occur prior to Authority to Proceed (ATP) for system production. For a typical military program this would include the conceptual and validation efforts, while for a commercial program it would include the marketing, preliminary design and program development efforts.

On a commercial program the first contractor step is to develop concepts and solutions or configurations in cooperation with the potential users. Following this, the program details are developed in sufficient depth to obtain contractor management go-ahead for further marketing. Then the selected approach is developed and aggressively marketed. During this process, continual give and take between the customers, both individually and collectively, are realized. A program approach is developed and priced, and offerred to the customers along with a delivery schedule. At this point, for the first time, the customers assume a prime role when they decide whether or not to buy. However, the final, critical decision - whether or not to commit to production - is made by the contractor, based on his own assessment of the program viability.

As discussed in the previous section, the responsibilities and roles on military programs differ markedly from those on commercial programs. The need for the new program must be identified and formally developed within the military establishment. Contractors may be invited to bid on developmental studies during the initial program phases. However, because of the more controlled, competitive nature, contractors on military programs have less flexibility to adapt and innovate than on commercial programs. This becomes increasingly so as a program proceeds from conceptual to validation efforts. Also, the more rigidized military approach necessitates a higher level of contractor commitment, earlier, than on commercial programs.

The period between the end of the Conceptual Phase and the invitation to bid on the Validation Phase may vary from several weeks to several months, or, at any time, the decision may be to not go ahead. During this period, those contractors interested in competing must support a gradual, unfunded build-up of all types of program personnel to be ready for the competitive effort. The period between the submittal of the proposal and receipt of the production go-ahead may also vary from several weeks to several months. When a program has gone this far it usually continues into production, but cancellation is always a possibility. During this waiting period, the contractor must sustain most of the large team developed for the proposal, usually on a wholly, or largely unfunded basis.

Analysis of the DC-9, C-9A and AWACS programs initial planning activities will illustrate the differences in contractor commitments.

1. DC-9

Company-funded Advanced Design Studies on a compact jet aircraft started in February 1956, Figure 10. Fifty-eight months later, following numerous design studies and discussions with airline representatives, a configuration was selected for commercial promotion. During this period, studies of varying depth were made, terminated and succeeded by new studies. The engineering manpower varied accordingly, but averaged approximately 2 men over the entire period.

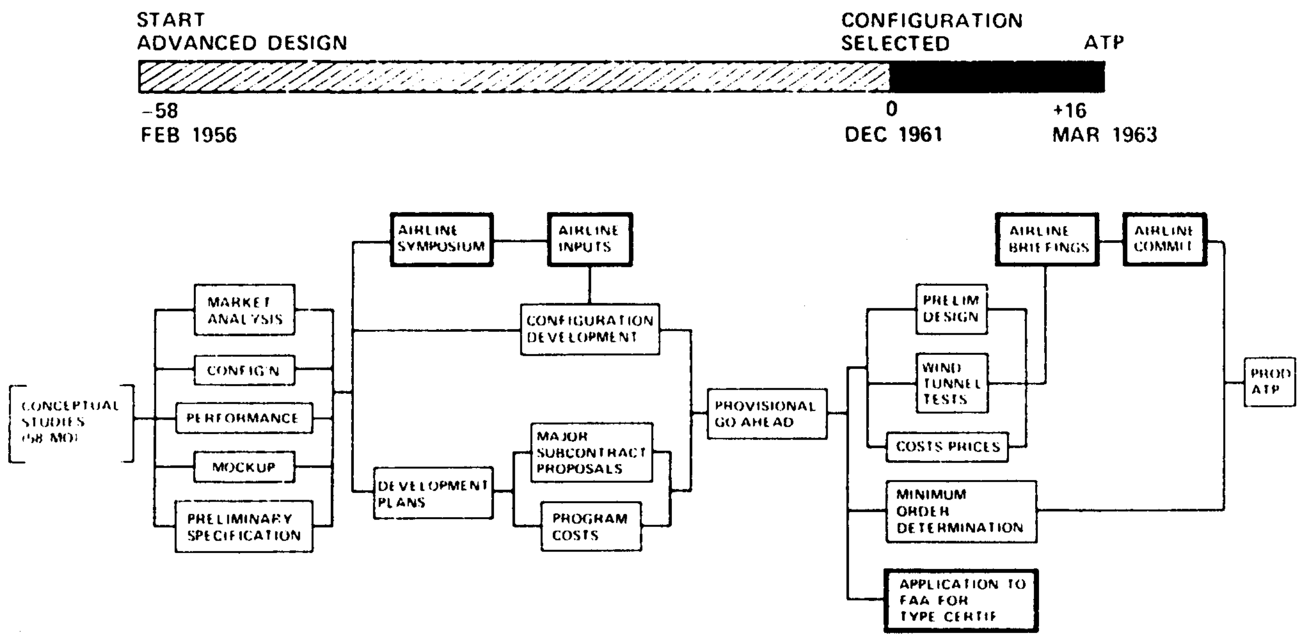


Figure 10. DC-9 Initial Planning Activities

Promotion of the selected configuration to the airlines and development of program plans and costs, somewhat comparable to Contract Definition, required 16 months. A formal symposium was held to discribe the aircraft and the program to the airlines, the interested airlines suggested specification changes and the configuration was refined and briefed to the airlines on a continuing basis. The engineering design effort during this period peaked at approximately 75 men.

2. C-9A

In August 1961, the first USAF action occurred to formalize a requirement for a replacement for the C-131 Aeromed aircraft, Figure 11. Douglas became involved five months later when a briefing on the new DC-9 aircraft, which was being proposed to the commercial airlines, was made to USAF personnel. Analytical and technical data were developed using company funds and supplied to the USAF during the next 50 months. The engineering effort during this period averaged approximately 2 men, similar to the commercial DC-9 effort.

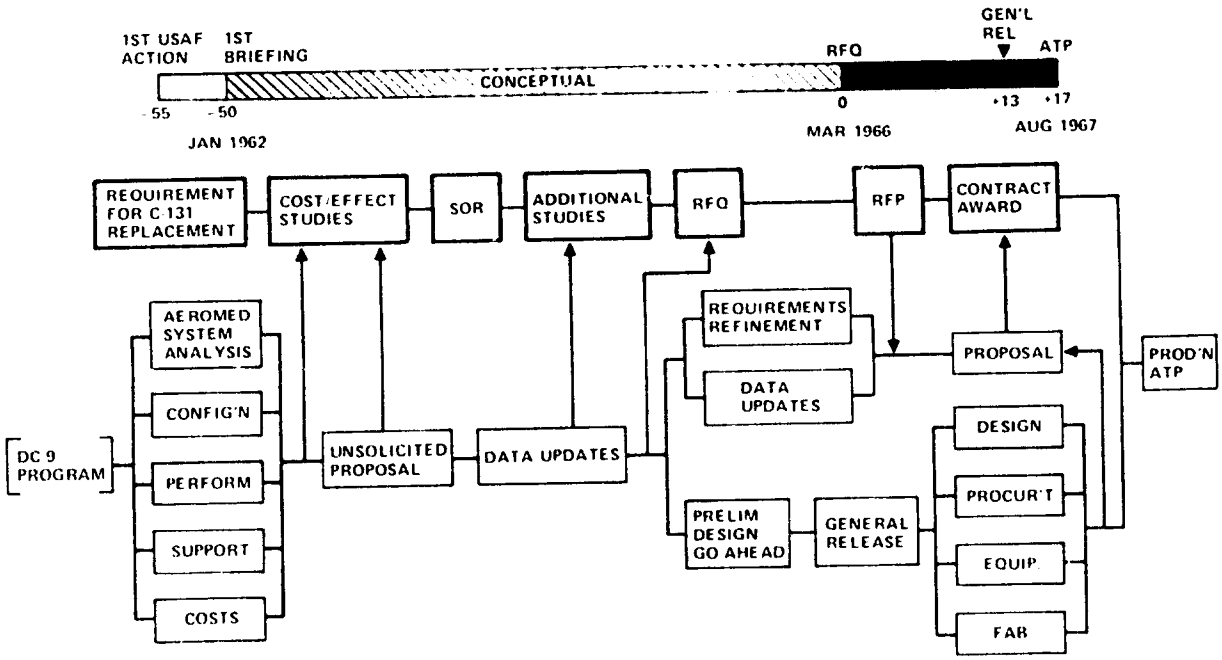


Figure 11. C-9A Initial Planning Activities

In March 1966, a request for quotation was received. This event may be considered to be the start of the type of activities normally associated with Contract Definition. The aeromedical evacuation system requirements were refined, aircraft performance, support and cost data were updated and a proposal for acquisition was developed during the next 17 months, still using company funds. Prior to receipt of the RFP for acquisition, a decision was made by Douglas to go ahead on company funds in anticipation of a contract, and a general release was made 4 months prior to contract award. The engineering design manpower peaked at approximately 110 men during the 17-month period.

3. AWACS

Douglas received USAF funding for a 7-month competitive AWACS Feasibility Study in May 1965, Figure 12. Eight months after the Feasibility Study, funding was received for a 14-month competitive Conceptual Study. Fourteen months after the Conceptual Study, funding was received for 18 months of Contract Definition. The DC-8 had been in commercial operation for 5-3/4 years when the Feasibility Study started, yet the engineering design effort devoted to satisfying the air vehicle data requirements during the Feasibility and Conceptual Studies averaged approximately 50 men.

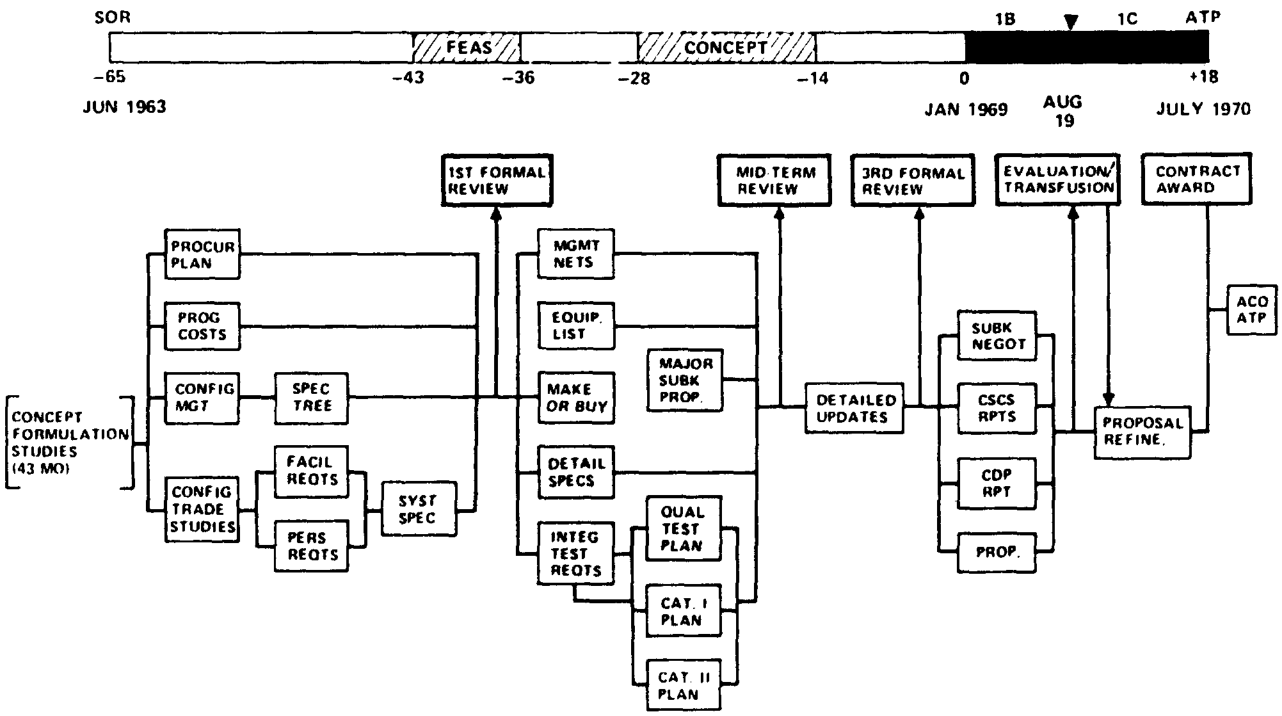


Figure 12. AWACS Initial Planning Activities

After 43 months involvement in the AWACS program, a fixed price contract was received in January 1969, for a 7-month competitive Contract Definition Study. Three formal reviews were required during the study and a final CDP report and Acquisition Phase Proposal were among the end products. As discussed previously, the Douglas Submittal at the end of CDP totaled 38,911 pages per set and cost approximately $1,067,000 to prepare.

The DC-8 had been in commercial service for 9¼ years when CDP started. The engineering design effort devoted to the air vehicle during CDP peaked at approximately 300 men.

The three reviews noted previously involved large numbers of people, Table 13. The first and third reviews were held at Douglas, Long Beach and were attended by approximately 125 and 325 government personnel, respectively. The second review was held at Hanscom AFB, and was attended by 80 Douglas people, plus an unknown number of traveling government employes. The Douglas travel and per diem bill for this meeting exceeded $40,000.

TABLE 13. COST OF AWACS CDP REVIEWS

	FIRST	MIDTERM	THIRD
LOCATION	DAC	HANSCOM AFB	DAC
TRAVELING PERSONNEL	125 GOVERNMENT	80 DAC ? GOVERNMENT	325 GOVERNMENT
HOURS EXPENDED			
PREPARATION	5,000	3,200	13,000
PARTICIPATION	5,000	3,200	13,000
	10,000	6,400	26,000

DAC EXPENSE FOR THREE REVIEWS ON A 6-MONTH FIXED PRICE STUDY:

42,400 HOURS ($848,000)

Assuming that Douglas matched their government guests on a one-on-one basis for the two meetings at Long Beach, spent one week preparing for the meeting and one week participating and reporting on the meeting, a total of 36,000 man-hours were expended. The meeting at Hanscom added another 6,400 man-hours.

The result is that 42,400 contractor man-hours, or $848,000, were spent in three reviews on a 6-month fixed price contract following 43-months of prior effort. This estimate is conservative, possibly by a factor of 3 or 4.

C. DESIGN ENGINEERING

Responses to the management questionnaire (Section II D) indicated a general attitude among experienced design people that greater applications of specifications and data requirements on military programs do not necessarily result in a better product. It is felt that the major aircraft manufacturers always strive to provide a quality product, whether commercial or military, and that additional quality gained as a result of the military specification program is marginal, costly and, therefore, hard to justify.

Major aspects of Design Engineering on military and commercial programs which are discussed to point out significant differences include:

- Military specification application
- Structural design

1. Military Specification Application

As shown previously in Table 2, the military specifications, standards, regulations, etc., imposed on the AWACS program exceeded those noted in a DC-8-62 Detail Specification by a factor of 7. These regulatory controls on AWACS ranged from the broad aspect of Civil Air Manual, Part 4 b, which was the basic design specification for the DC-8, to MIL-E-22285 which called out Drawing AN 742 for clamps to hold the tubing for the fire extinguishing system. Many top level specifications were listed in Section 2.0, Applicable Documents, of the System Specification, often with no specific callout elsewhere. Many specifications were called out with no apparent awareness of the nature of the procurement. That is, the basic airframe, which had been in commercial production for more than nine years at the start of the Contract Definition, was being subjected to the same set of requirements that would be imposed on a totally new development.

In an effort to avoid costly redesign and requalification of a thoroughly proven airframe, a specification deviation program was necessary, Table 14.

TABLE 14. AWACS SPECIFICATION DEVIATION PROGRAM

INITIAL PRE-CDP SUBMITTAL

- 199 ITEMS, 2 REVISIONS
- ONE MAN-YEAR EXPENDED FOR SUPERVISION

ON-GOING EFFORT THROUGH CONTRACT DEFINITION

BASIC MIL-SPEC PROBLEMS

- RELEVANCE TO SPECIFIC PROGRAM
- CURRENCY
- "HOW TO" vs "WHAT"

This effort was initiated prior to CDP, was continued during CDP and would have continued into Acquisition. While this effort is difficult to quantify because it involved many functional groups to varying degrees, it has been estimated, probably conservatively, that over 11,000 engineering hours were expended on the specification deviation analysis. Using the composite industry rate, this converts to a cost of more than $220,000.

In addition to those problems created by the sheer number of specifications noted in the AWACS System Specification, problems also arose because some of these were not relevant because of the nature of the program, some were no longer current, while many told the contractor how to design the system rather than what is required, Table 15.

TABLE 15. AWACS MILITARY SPECIFICATION PROBLEMS

	RELEVANCE	CURRENCY	"HOW TO"
SUBJECT:	SYSTEMS ENGINEER'S VISION	RETRACTABLE ENGINE INLET SCREENS	WASHER MATERIAL
REFERENCE:	AFSCM-80-1	AFSCM-80-1	AFSCM-80-1 (HIAD)
REQUIREMENT:	SEE NACELLES AND OVERFLOW PIPES WHILE SEATED	MOUNT MIL-S-25057 SCREEN IN INLET DUCT	USE AN960 PLAIN WASHERS FOR LOW STRENGTH FASTENER APPLICATIONS
DEVIATION REQUEST:	DELETE REQUIREMENT	DELETE REQUIREMENT	USE PRESENT DC-8-62 WASHERS
REASON:	REFERS TO NEW DESIGNS, INCOMPATIBLE WITH DC-8 FLIGHT DECK.	OUTDATED PRACTICE	MORE CORROSION RESISTANT AND LIGHTER (40 LB PER AIRCRAFT)

In addition to the dollar cost of a specification deviation effort, there is another significant problem which may be even more costly to a program. In actual practice, negotiations of deviation requests comprise a long, drawn-out process. Reasons for this include basic disagreements between the contractor and the cognizant government agency, misunderstandings due to poorly written deviation requests, and loss of continuity due to personnel changes. Until the deviation is approved, the contractor must conform to the specification or risk the consequences of not receiving approval. In either case, valuable time and resources may be expended needlessly.

2. Structural Design

In general, full scale structural testing on commercial programs is less stringent than on military programs. As a result, very sophisticated tools have been developed for the optimization of materials, structural sizes and structural weights, and also to provide very detailed stress analyses, aircraft aeroelastic analysis, fail-safe analysis, and fatigue analysis. With these tools, a contractor is able to duplicate failures of structural components and assemblies, determine the residual strengths and meet the FAR Part 25 fail-safe requirements.

In designing for residual strength, the required minimum structural element failure levels are exceeded. This tends to increase the 1 g stress level which in turn, increases the fatigue life as well as the time before crack propagation becomes a problem. For example, a DC-10 wing crack, two wing bays long with a broken central stiffener, can sustain 100 percent of the design limit gross stress. For this damage condition, the design ultimate gross strength is approximately 128 percent of the undamaged condition. By comparison, the C-5A was designed to 100 percent of the ultimate strength, not allowing sufficient reductions for fatigue; early cracking and rapid crack growth were the results. A recent military solution to this type of structural problem was to create a more severe specification, MIL-83444, to prevent future aircraft from being designed without sufficient fail-safe capability, damage tolerance and early cracking resistance.

This tendency to generate increasingly stringent military specifications for problems makes it increasingly difficult to design efficient military aircraft. In recent years, the severity of turbulence that an Air Force airplane must sustain has been increased. This is directly reflected by an increase in loads and structural weight imposed by the MIL-8860 series of specifications. If specification requirements result in increased weight, they tend to reduce the performance without necessarily affecting the safety margin.

The civil aircraft authorities have generally permitted the commercial manufacturers more flexibility of design. When problems such as turbulence upsets arise, the FAA and the contractor work out solutions and notify the operators as to the best course of action. For example, in the 1960's, jet aircraft upset during turbulence was suspected of causing catastrophic incidence of high vertical load factor excursions during recovery from the upset; at least 11 suspected occurrences were recorded. The action taken to solve the problem was Advisory Circular No. 120-5 from the FAA Director of Flight Standards that advised a recommended procedure for turbulent air penetration. The various aircraft manufacturers visited all operators of their products to advise them of the recommended procedures. Since the publications of the circular and the contractor visits, no catastrophic upset incidences have occurred.

3. YC-15 Design Approach

To meet the design requirements and goals noted in the RFP (Section II A-4), Douglas implemented design-to-cost practices on all aspects of their AMST program, designated as the YC-15 program.

The initial design reflected the overall funding limit. However, without an aggressive cost reduction follow-on, the program would have been little different from past procurements wherein, once costs were negotiated, the management emphasis was on justification, rather than reduction of the costs. The Technical Director and his Manufacturing and Tooling counterparts worked together and within their respective organizations not only to maintain cost-consciousness, but to constantly seek out cost reductions.

Certain requirements for the prototype and goals for the production aircraft were quantified; however, the design of several very significant items was left largely to the contractor, Table 16. Crew compartment pressurization was required, but no specification pressure schedule was called out. The communication/Navigation system is required only to have "adequate capability". Similarly, cruise speed is to be "normal" for a jet transport and the aircraft handling qualities, usually the subject of exhaustive MIL-SPEC analysis, are to be "excellent". The designers are thus given the flexibility required to make the tradeoffs necessary to satisfy the system needs within the given cost ceiling.

TABLE 16. AMST REQUIREMENTS AND GOALS

REQUIREMENTS	GOALS
CARGO COMPARTMENT SIZE 11.3 FT x 11.7 FT x 47 FT	$5 M FLYAWAY COST FOR 300TH ARTICLE (JAN 1972 DOLLARS)
10.5 FT UNDERWING CLEARANCE	PAYLOAD RADIUS: 27,000 LB/400 N MI AT 3G; 53,000 LB/400 N MI AT 2.25 G
INTEGRAL RAMP	
TRUCKBED HEIGHT LOADING	2600 N MI FERRY RANGE, INTEGRAL FUEL
500 HOURS GROUND AND FLIGHT TEST	NORMAL TRANSPORT CRUISE SPEED
PRESSURIZED CREW COMPARTMENT	EXCELLENT HANDLING QUALITIES
ADEQUATE COMM/NAV SUBSYSTEM	SIMPLE, EASILY MAINTAINED AIRCRAFT

One of the first major tradeoffs on the YC-15 was a small reduction in cruise speed to achieve major cost savings. The proposal design included a swept wing; however, subsequent studies showed that a straight wing design would greatly reduce design and manufacturing costs at the expense of .06 M in cruise speed. Inasmuch as the prototype mission can easily be achieved at the lower speed, the tradeoff was approved. Constant cross-sections in the tail and a circular fuselage were major constributions to low manufacturing costs. Heavier skin gauge permitted increased frame and stringer spacings to reduce parts and manufacturing costs while satisfying structural requirements.

Fasteners, hole sizes and countersink sizes were standardized to reduce manufacturing times. Larger machined elements were designed to eliminate subassembly build-ups where practical. Adhesive bonding was used in place of individual fasteners in selected areas. Bend radii of sheet metal parts were selected to permit forming without special treatments.

In areas where little or no aerodynamic effect would result, dimensional tolerances were relaxed. Thus, common round head rivets were used externally on the aft cargo door instead of flush with their requirement for countersinking.

MANUFACTURING/PRODUCTION

1. Fabrication and Assembly

Perhaps the greatest manufacturing cost driver on a military derivative of a commercial aircraft is the imposition of peculiar change on an existing production line. The establishment of a moderate-to-high-rate production line involves an extremely large amount of planning and investment for facilities, tooling, fabrication equipment, material, assembly jigs and procedures. One of the keys to an efficient production run is maximum standardization. In general, for each given commercial airplane type, there is a basic airframe; the major elements such as the fuselage, basic wing, landing gear and tail are the same. The changes between similar commercial aircraft that impact most on cost are those involving the interior and the engines. The price of a distinctive interior is an accepted expense in the competitive airline business. Within limits different engine installations may occur, but the major recurring cost difference is that for the engines themselves, not their installation.

For military derivatives, changes to the basic production model may be specified to remove certain commercial items that are not necessary for the military mission, to meet a MIL-SPEC requirement or for other reasons. Two examples for the AWACS program will illustrate the cost impact of seemingly small manufacturing activities.

Because the AWACS airplane will not spend much time in icing conditions, it was suggested that the wing and horizontal de-icing systems be deleted. It was thought that maintenance savings on the cyclic valves, plus cost and weight savings, would justify this change from the basic DC-8 configuration.

An analysis was made of the paperwork which would be generated by the Manufacturing Planning group to delete the wing and horizontal tail de-icing system components, Table 17. The flow-down of paper required for subassembly and part identification and handling results in a total of 864 individual pieces of paper being generated. For the initial release, an average of eight hours preparation time was estimated, for each of three subsequent releases, four hours would be required. The result is that $272,500 would have been spent on Manufacturing Planning alone to delete the de-icing system.

To satisfy MIL-SPEC requirements for corrosion control on the AWACS it would have been necessary to apply wet primer material to all external fasteners during assembly. The DC-8 which does not have the primer, had been operating world-wide for over nine years with no significant corrosion problems.

TABLE 17. COST OF MANUFACTURING PLANNING CHANGE

SUBJECT: DELETION OF DC-8 DE-ICING SYSTEM FOR AWACS

REASONS: SAVE COST, WEIGHT AND MAINTENANCE

DECISION: REMOVAL NOT JUSTIFIED

COST ITEM: PAPERWORK TO EFFECT CHANGE

PLANNING PAPER	864 PIECES
PREPARATION TIME	8 HOURS EACH FOR INITIAL RELEASE
	4 HOURS EACH FOR THREE SUBSEQUENT RELEASES

17,280 HOURS ($272,500)

There are in excess of 100,000 external fasteners on the DC-8, many of them installed by automatic processes. Production estimates indicated that over 1900 hours would be added to the time to produce each AWACS airplane, an additional cost of approximately $30,000.

The C-9 programs have saved considerable costs by accepting commercial practice as regards standard improvements. In the course of the production life of a given aircraft type, certain improvements will be made which may alter the basic design slightly, but which do not impact on performance, cost or schedule. These are routinely worked into the line and all aircraft produced subsequently include the change. Initially it was specified that all C-9A aircraft would be the same; that is, they would not include the standard changes. The impact of this would have been to intermix an occasional unique configuration with standard airframes on the line. This would, in turn, require special fabrication and assembly orders for the unique parts, plus special inventory control and inspection. The cost implications of this special handling were reviewed and the decision was made to follow the conventional commercial practice.

2. Quality Assurance

Government Quality Assurance requirements impact the contractor's management system in addition to measuring the contractual compliance and quality of his hardware. To satisfy these military program management requirements, it has been necessary to establish procedures and records different from those practiced on commercial programs.

Specific areas of difference include:

a. Quality System Audits

Although the Douglas A-4 Skyhawk program has been in existence for more than 25 years, a continuous quality system surveillance audit is maintained by the government. Quality Deficiency Reports are prepared for all observed deficiencies and each report must be investigated by the contractor and a satisfactory disposition reached with the customer. In addition to production deficiencies, reports are made on procedural deficiencies even though they have no impact on the product. No such audit is practiced on commercial aircraft.

b. Material Review

On military programs, a government representative participates as a member of the Material Review Board to determine whether material which does not meet contractual requirements can be used for its intended purpose or any other purpose. Over zealous interpretation of specifications may result in costly scrapping of material whose fault (e.g., a nick in an unstressed area) has no impact on its intended use. On commercial programs, the contractor performs this function judiciously with no adverse effect on safety.

c. Product Identification

Military Standard 130D imposes identification requirements in excess of those required on commercial programs. For example, this standard requires a contractor to put his Federal Code Number on all aircraft parts and spares, delivered to the government. Compliance requires new tags, stamps and handling procedures. These added requirements impose another, unnecessary source of costs for compliance.

3. YC-15 Tooling

An interesting example of tooling design-to-cost, suitable for the limited YC-15 production, is provided by the process used to stretch certain fuselage skins, Figure 13.

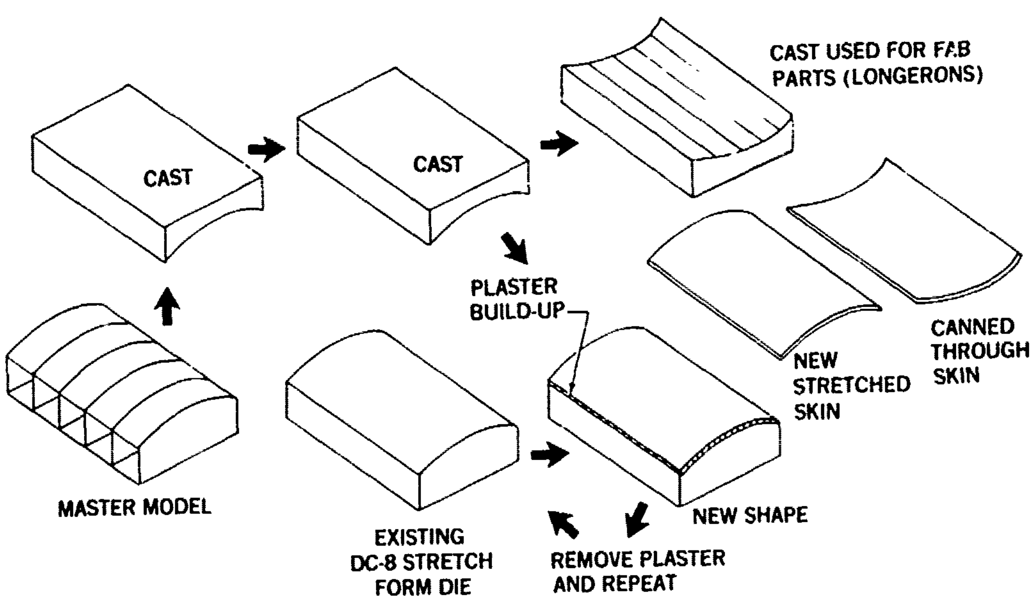


Figure 13. YC-15 Low Cost Tooling

A Master Model was made inexpensively of birch plywood frames coated with sensitized material, upon which full scale tooling drawings were photographed. The contour was built up with plaster from which a plaster cast was made. From the boneyard, an existing Kirksite stretch form die was recovered which somewhat matched the new shape. The cast and die were bolted together and a plaster build-up was made on the Kirksite die. The cast was then removed and used as a form guide for hand-shaped longerons. Skins for each airplane were stretched on the die, then the plaster was broken off and the Kirksite used again, if suitable. Where right and and left hand skins were exact opposites, two skins were stretched on the same die, then one was simply "pushed through" to produce the reverse curvature. This eliminated the need for the cost of an opposite die.

E. TEST/EVALUATION

The test and evaluation functions cover those laboratory, ground and flight test activities which occur during development and production. This section discusses the differences between the full military specification requirements for structural integrity testing on AWACS and an alternate, low cost, commercial type approach. Also, the DC-9-10 commercial flight test program is compared to that proposed for the U. S. Navy S-3A program.

Commercial airworthiness test programs are accomplished to plans agreed upon between the contractor and the FAA. Test plans are developed and tailored to meet specific program objectives. Specific tests may be witnessed by the FAA, while others may be certified by the Designated Engineering Representative as having been accomplished according to the plan and having met the stated test objectives. System operational evaluations, such as reliability and maintainability, are generally based on actual use by the customer, rather than on preliminary demonstrations.

Military testing is developed in accordance with formalized specification requirements developed for application to a wide spectrum of aircraft. A hierarchy of testing exists, ranging from simple components to the complete air vehicle, and covering personnel, AGE, reliability, etc. Generally, the definition of requirements, the development of individual and integrated plans and the accomplishment, reporting and approval of this hierarchy are formalized, sequential procedures. The development of large amounts of formalized data such as detailed plans, procedures, reports for hardware, personnel and facilities, plus the delays inherent in such a practice, are major cost factors.

Ground and flight testing on derivative commercial programs is tailored to reflect the nature of the change, past experience and the results of design analyses. Common components generally are not tested, only those peculiar to the change.

1. Structural Integrity Programs

Commercial practice in the area of structural integrity relies heavily on detailed analyses and developmental testing of components prior to final drawing release. In addition to this testing, one production aircraft is tested to 100 percent of its design limit loads, then refurbished and sold. To be sure that all the load conditions are known, full scale structural components are tested on jigs. For example, on the DC-10 program three major full scale structural sections (wing and center fuselage, nose, tail) were tested separately, but concurrently. In this manner, a great deal of fatigue data were accumulated in a relatively short time. Test problems were remedied and the change results incorporated into the production design before in-service problems could arise. By August of 1972, 44 DC-10 aircraft had been delivered to various airline customers and the high time airplane had ammassed about 5000 flight hours. However, by that time, the ground test program had tested a production aircraft to its full design life of 120,000 flight hours. The military requirement of one full scale fatigue test could not have run as quickly, would not have had the load coverage, and, therefore, would not have produced the desired structural data early enough to keep the cost down by early recognition of the small structural changes required.

The AWACS structural integrity program had the background of over 9 years of commercial DC-8 operations. The total fleet had amassed over 7,500,000 flight hours, with high time aircraft over 40,000 flight hours. No significant failures in primary structure had ever been reported. The AWACS RFP, however, required a complete structural integrity test program, Figure 14. This program included revalidation of the basic airframe structure with the AWACS modifications. However, the RFP also stated: " . . . it is the desire of the U. S. Air Force to take full advantage of the off-the-shelf status of existing air vehicle systems . . . where specific military specifications relating to performance and design are identified in this RFP. . . the contractor may propose alternate specification. . ." Therefore, to effect major cost savings, Douglas proposed an alternate approach, Figure 15:

a. Eliminate testing of identical DC-8 components and structure. Verify by inspection and qualitative demonstration.

b. Minimize testing of DC-8 similar components and structure. Verify by analysis and limited testing. Use MIL-SPECS for guidance rather than strict adherence.

c. Comply fully with MIL-SPEC requirements for new and unique components and structure.

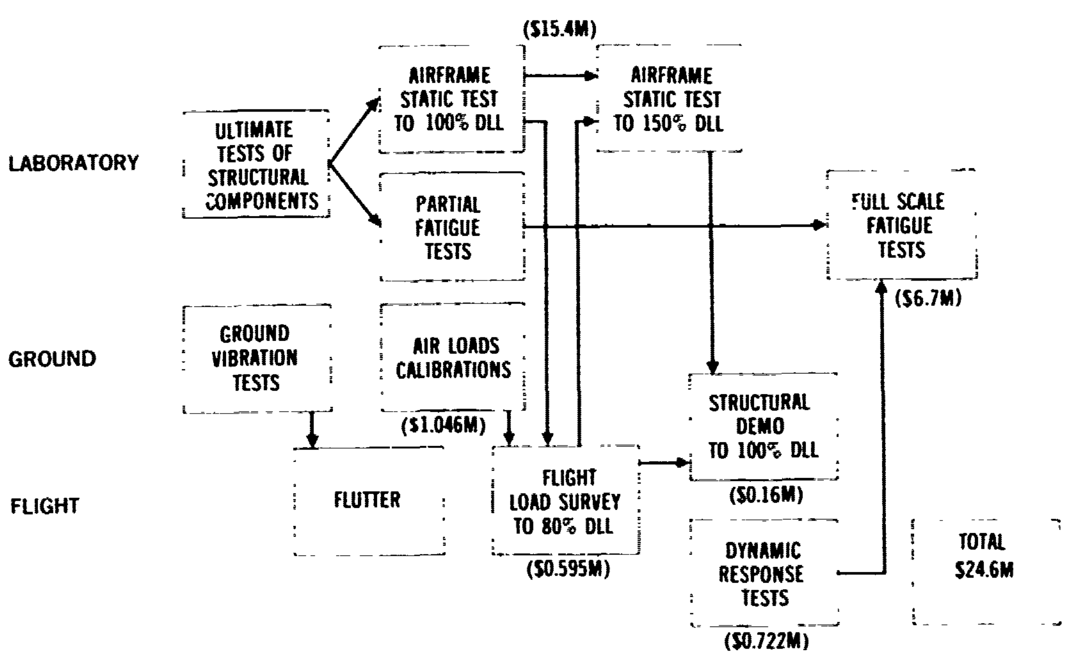


Figure 14. AWACS MIL-SPEC Structural Integrity Program

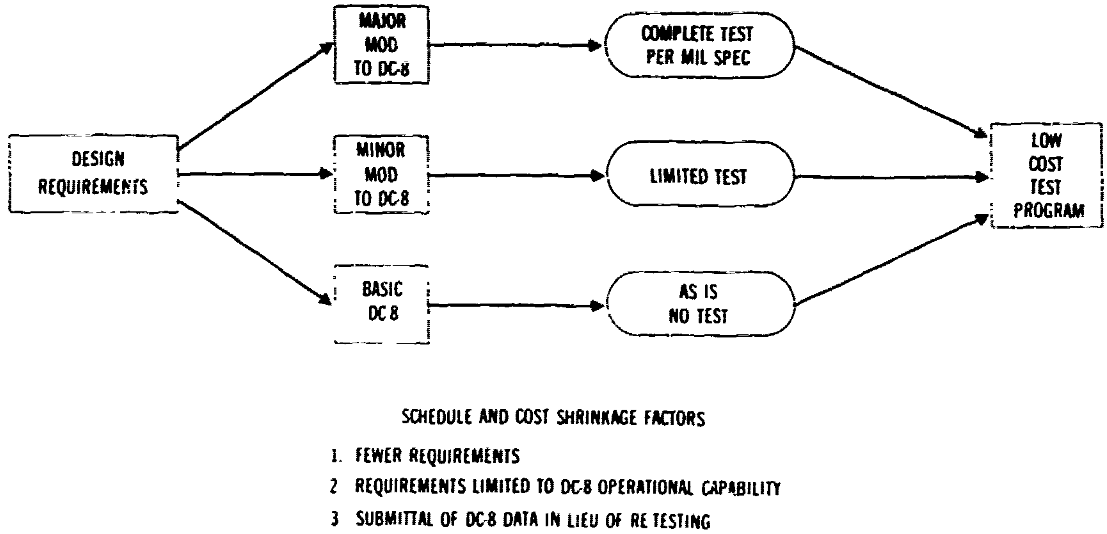


Figure 15. Proposed AWACS Low Cost Structural Test Approach

The resultant program, Figure 16, was estimated to provide a cost savings of approximately $24.6 M. The deviation requests necessary to implement the low cost program were under negotiation at the time of Acquisition Phase go-ahead.

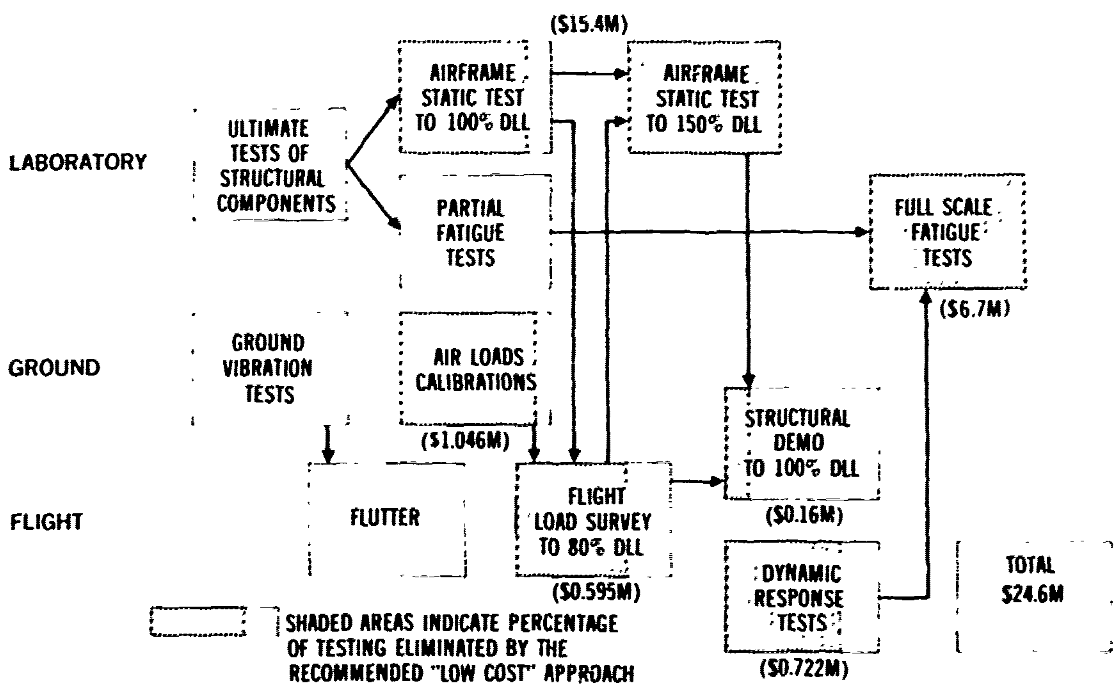


Figure 16. AWACS Low Cost Structural Test Approach

2. Flight Testing

In many cases, military flight testing requires more time and involves more cost for one or more of the following reasons:

- Programs push state-of-the-art
- Integration problems are complex
- Operational requirements may be multi-mission

In such instances, the time and costs involved in rigid adherence to MIL-SPECS and tighter program control can be justified. However, on many non-vital, derivative programs,significant savings can be realized by treating the test program essentially as a commmercial configuration change. For example, the derivations of the C-9A, C-9B and VC-9C from the commercial DC-9 did not alter the exterior lines or the general weight and balance of the airplane. Therefore, the basic DC-9 flight certification was applicable and accepted by the military agencies. The only special flight testing on the C-9 derivatives was that required for checking out new or modified systems (e.g., navigation and environmental control) and these tests were done in accordance with FAA specifications.

A reasonably direct comparison between commercial and military flight testing on new airplanes is furnished by the DC-9 and U. S. Navy VSX (S-3A) program. The DC-9 had been in commercial service for 2¼ years when the VSX proposal was submitted to the Navy. Much of the highly successful DC-8 airframe design approach had been incorporated in the DC-9 and in-service records had already indicated its high quality. Similarly, the VSX airframe design drew heavily on the DC-9, both had engines mounted on the aft fuselage, horizontal tails mounted up on the rudder and both represented the same overall state-of-the-art.

The flight testing required to certify the DC-9 and to achieve the equivalent Navy Inspection and Survey (INSURV) for the VSX air vehicle is compared in Table 18. Despite its close design relationship with the DC-9, the VSX air vehicle, excluding mission avionics, weapons and carrier suitability tests, required more flight hours, stretched out over a much longer period. Part of this difference is due to two specific reasons: (1) the DC-9 flight test program was accelerated so as to identify all necessary changes by the start of production and (2) certain accommodations were necessary in the VSX schedule for avionics system testing, although the numbers shown are the actual schedule hours for the air vehicle only.

The DC-9 test program was accelerated at the discretion of the manufacturer, no outside agency approval was requested. The basing and support of the program was under his control and appropriate authority was at hand for timely decisions. The VSX program, on the other hand, was to be conducted and supported at a military base. Daily and weekend overtime authorizations would not have been as readily avilable. Formal test reporting and approval cycles, plus long range decision-making for requested changes would have consumed more time. The VSX schedule reflected this longer,but more typical,approach to military programs.

TABLE 18. FLIGHT TESTING REQUIRED FOR CERTIFICATION/INSURV

	DC-9-10		VS(X)	
	FLT HR	ACFT MOS	FLT HR	ACFT MOS
AIR VEHICLE TESTS	789	18.5	964	41.0
CERTIFICATION/INSURV	441	9.0	460	8.0
	1230	27.5	1424	49.0
			(+ 15%)	(+ 78%)

OTHER VS(X) TESTS

MISSION AVIONICS

CARRIER SUITABILITY

WEAPONS SEPARATION

The military practice of Preliminary Evaluation is also a factor which adds to cost by creating duplication and delay. Shortly after the start of flight testing, and several times thereafter, the flight test program is halted for one or more weeks while a military review team is checked out on the aircraft, then duplicates much of the contractor's tests to date, to ensure that the aircraft is performing during this period. A less costly approach to Preliminary Evaluation would be to have military pilots and flight engineers participate in the contractor's test program or to conduct all tests under the Joint Test Force approach recently implemented on programs such as the AMST.

3. System Performance Demonstrations

On military programs, demonstrations of special system performance, such as reliability, maintainability, survivability, personnel subsystem, safety, etc., are planned and accomplished concurrently with design development. For example, on AWACS, the program plans for these elements were due in the first 4 to 6 months of the 38-month DDT&E phase, updated as required, but no later than each 6 months. Testing and reporting in accordance with the previously approved plans was continuous - and repetitive - as the system configuration developed. As a result, changes in the system configuration which occurred as a result of Category I testing would have negated, for the areas of change, most of the documentation efforts of the previous two years.

Commercial practice is to conduct sufficient analysis and development testing,prior to delivery,to support the design effort and to establish objectives or goals for reliability, maintainability, etc. These goals then serve as bases for acceptance of the aircraft type by the operator.

To illustrate, Douglas established two mean-time-between-failure (MTBF) goals for some of the DC-9 equipment, Figure 17. The first goal was evaluated one year after the DC-9 went into commercial service. (The first six months of operation with each airline was not measured as it covered airline personnel training, mechanics and technicians getting acquainted with equipment, trouble-shooting, etc.). Therefore, the first

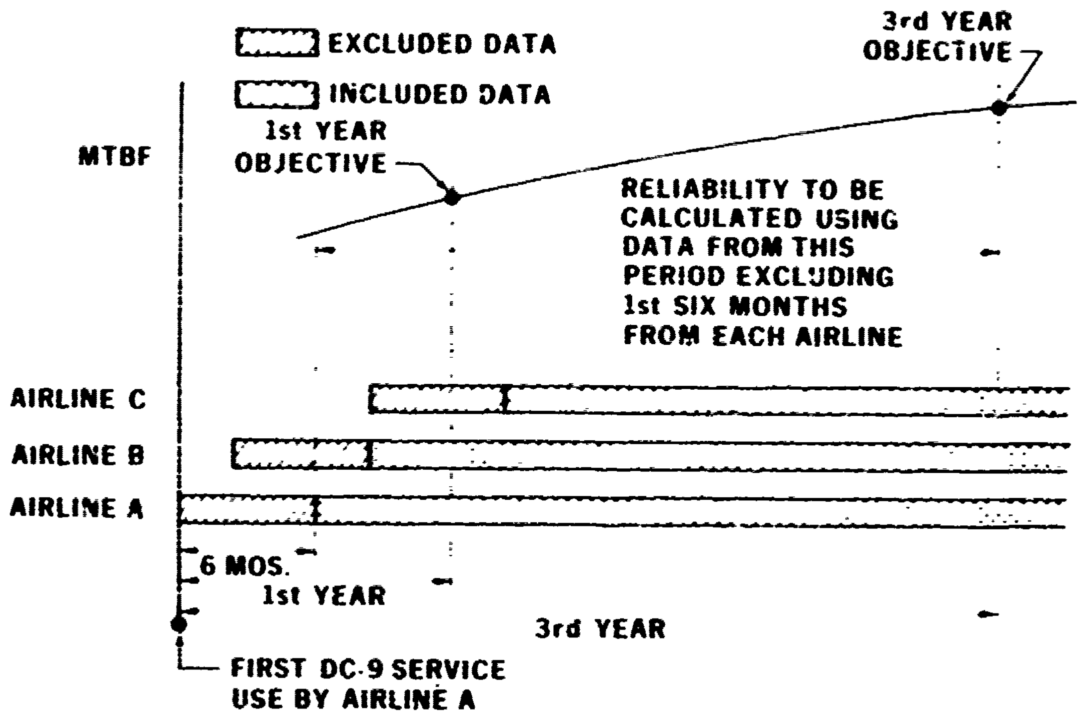


Figure 17. Equipment Reliability Measurement

year measurement included a full six months of operational time with airline "A" and approximately 3½ months with airline "B". The agreement between Douglas and the equipment suppliers was that if the first year goal was not met, the cause would be determined and corrective action taken.

The second DC-9 reliability goal was the third year MTBF. This goal was, of course, more stringent then the first year goal and the evaluation was based on a much greater data base. Again, the supplier was obligated to correct deficiencies.

Thus commercial evaluations are based on operational experience with the actual system, with only essential analysis and testing being accomplished during development.

F. OPERATIONS AND SUPPORT

As aircraft have become increasingly large and complex, they have created the

the need for new maintenance technology to ensure productive utilization. The predictive and monitoring techniques in practice today on third generation commercial jet aircraft, such as the DC-10 with approximately 3650 major line replaceable unit (LRU's), were undreamed of when the DC-3 was flying with approximately 350 LRU's. In fact, advancements in the past few years reveal startling improvement, Figure 18.

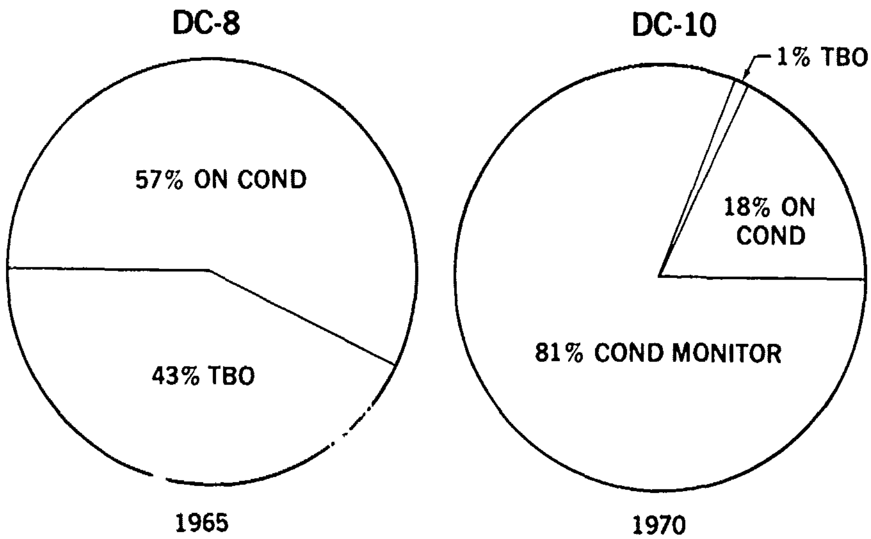


Figure 18. Maintenance Program Progress

In 1965, 43 percent of the required maintenance actions were performed whether or not the units had malfunctioned. The application of advanced planning techniques such as that explained in "Air Transport Association Maintenance Program Planning Document, MSG-2", have reduced the hard time maintenance actions on the DC-10 to 1 percent of the total. The major advance has been in the field of predictive analysis. Using these techniques, 99 percent of the DC-10 maintenance actions are performed in accordance with monitoring processes. These processes involve analysis of equipment performance to determine where problems exist. LRU's may fail gradually at a roughly linear rate or slowly at first, then at an accelerating rate, or instantaneously, without prior deterioration, Figure 19. Those items that deteriorate at a predictable rate and can affect flight or mission completion, are classified as either hard time or on-condition items. These remaining items, those that fail along gradual or accelerated lines and are not flight or mission critical, usually fall in the condition monitor category.

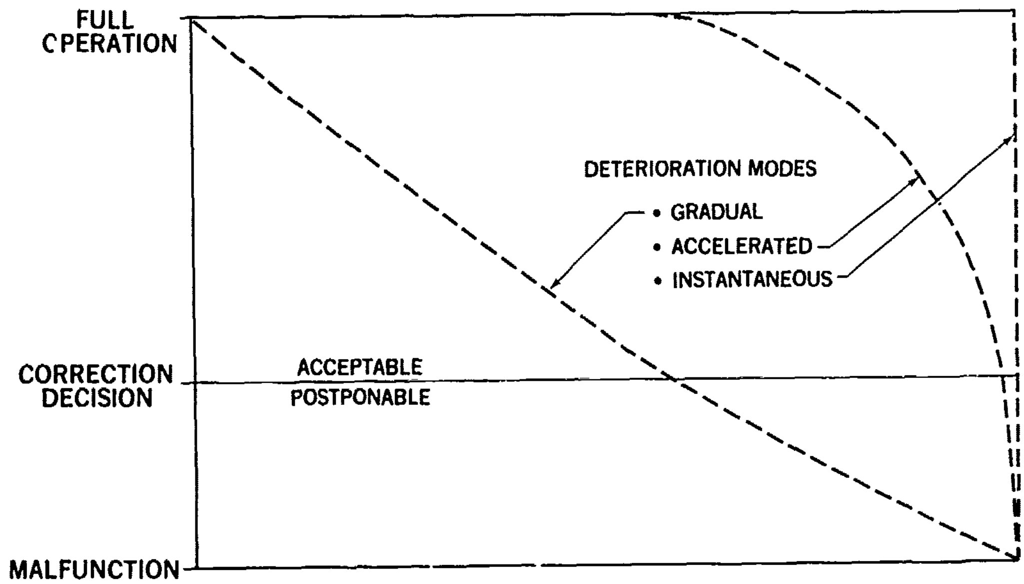


Figure 19. Predictive Analysis Parameters

The application of the predictive analysis concept to the DC-10 is shown in Figure 20.

1. C-9A Contractor Support

Even without the benefit of the advanced techniques just described, the C-9A Contractor Support Program has proven to be very successful in terms of cost savings and operational efficiency. However, a comparison of the C-9A maintenance practices with those of a very efficient commercial operator suggests procedures which may afford even greater benefits. The C-9A maintenance concept is essentially "remove and replace" with the exception of certain "on-equipment" functions as shown in Table 19.

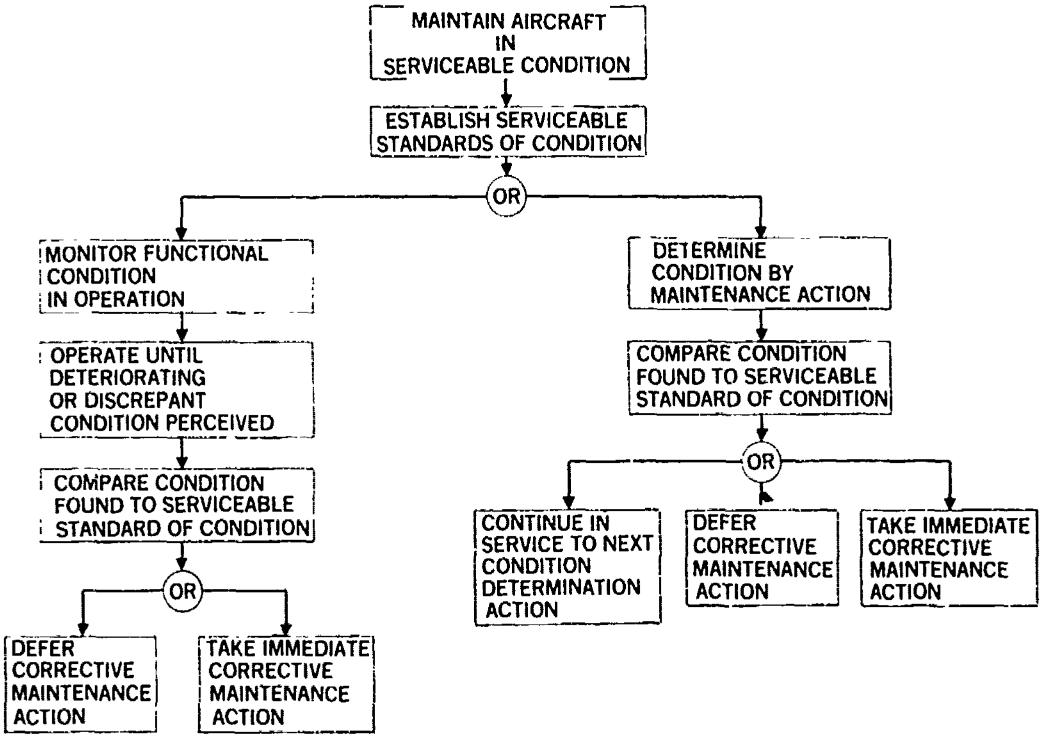


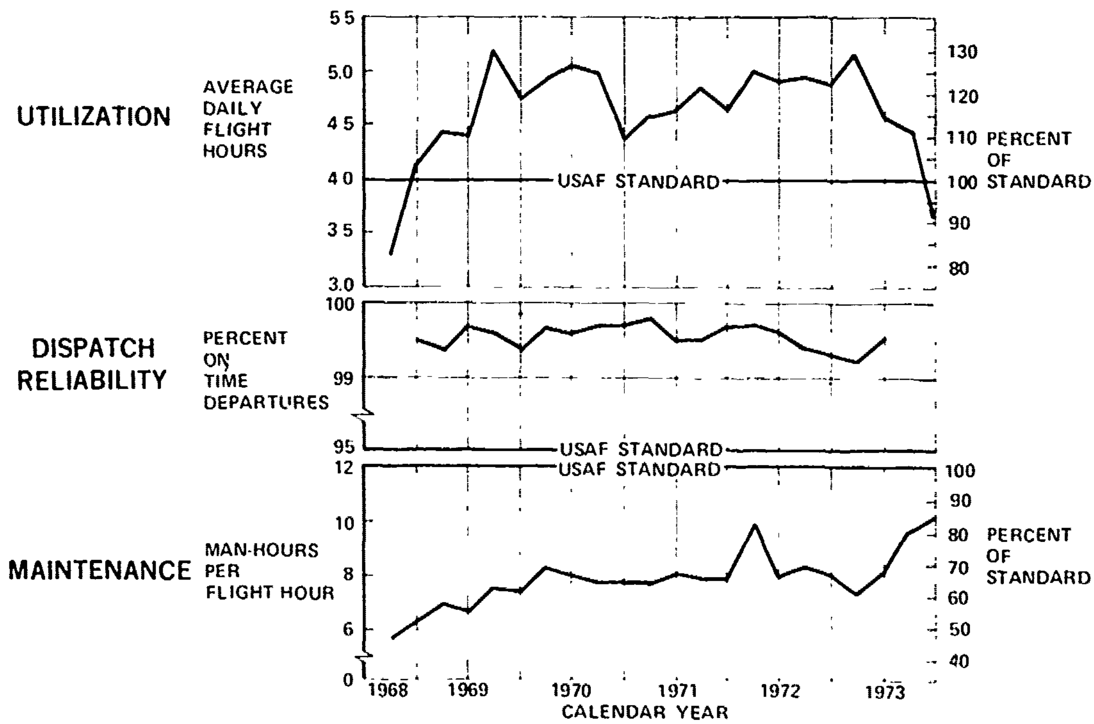
Figure 20. DC-10 Maintenance Concept

TABLE 19. C-9A CONTRACTOR SUPPORT PLAN

- AIR FORCE
  - "ON EQUIPMENT" MAINTENANCE ONLY
  - PROCURE PECULIAR AGE
- CONTRACTOR
  - SPARES SUPPORT
  - COMPONENT REPAIR/OVERHAUL
  - ENGINE REPAIR/OVERHAUL
  - MAINTAIN PECULIAR AGE
  - AGE CALIBRATION
  - TECHNICAL SUPPORT
  - IRAN
- INCENTIVE/PENALTY CONTRACT FOR CONTRACTOR PERFORMANCE
- FIVE-YEAR SAVINGS vs ORGANIC SUPPORT = 45%

The major contractor effort is spares support and an inventory of most-needed spares is maintained at each home base. Other higher cost, less needed spares are guaranteed to be available with prescribed time limits; the contractor draws on world-wide commercial spares pools and factory resources to satisfy these requirements. Major aircraft and systems maintenance functions are subcontracted to commercial operators. The contractor is rewarded or penalized for his performance against negotiated standards. USAF studies show that five year savings of approximately 45 percent have been realized when compared to full organic support.
been realized when compared to full organic support.

The recorded operational performance of the C-9A is compared to the contractual standards in Figure 21. During the latter months of the war in Viet Nam, utilization exceeded the standard of 4 hours daily by as much as 30 percent. The end of the war and the fuel shortage in 1973 saw a sharp drop in utilization, however.



DATA SOURCE MAINTENANCE PERFORMANCE DIGEST, 375th AAW

Figure 21. C-9A Operational Performance

Dispatch reliability is a measure of the on-time departure rate. A departure delay of 15 minutes or more detracts from this figure. C-9A dispatch reliability has never dropped below 99 percent, well above the standard of 95 percent.

The standard of 12 maintenance-man-hours per flight hour (MMH/FH) has always been bettered. Maintenance-man-hour requirements have averaged only two-thirds of this ceiling limit. The sharp rise MMH/FH in 1972 indicates the first major overhaul for the fleet, while the gradual rise in 1973 reflects the aforementioned drop in utilization.

The C-9A receives its maintenance checks on a calendar basis, Figure 22. Therefore, the intervals between maintenance actions have remained fairly constant, and are a direct reflection of its utilization rate of approximately 8 hours per day. Delta Airlines, on the other hand, set its DC-9 maintenance actions against hours of use. As the system matured and the data base grew, Delta periodically and successfully petitioned the FAA to increase the intervals and thereby reduced MMH/FH, with attendant cost savings.

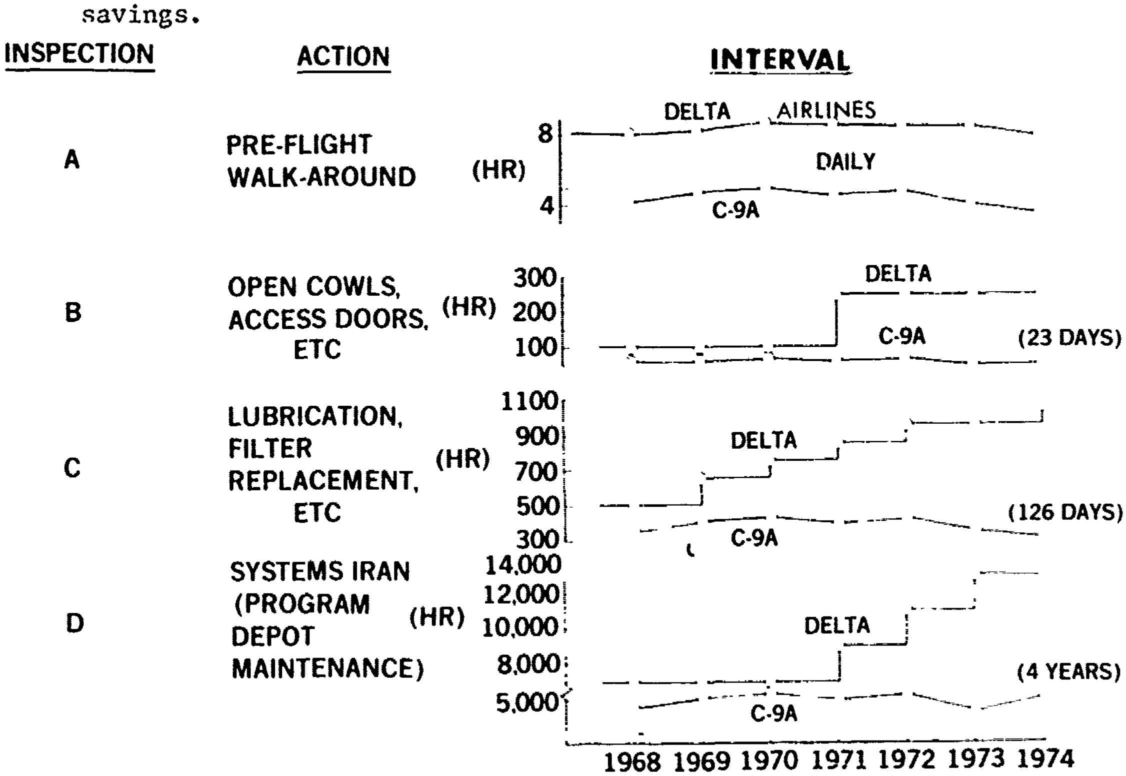


Figure 22. DC-9/C-9A Maintenance Inspection Intervals

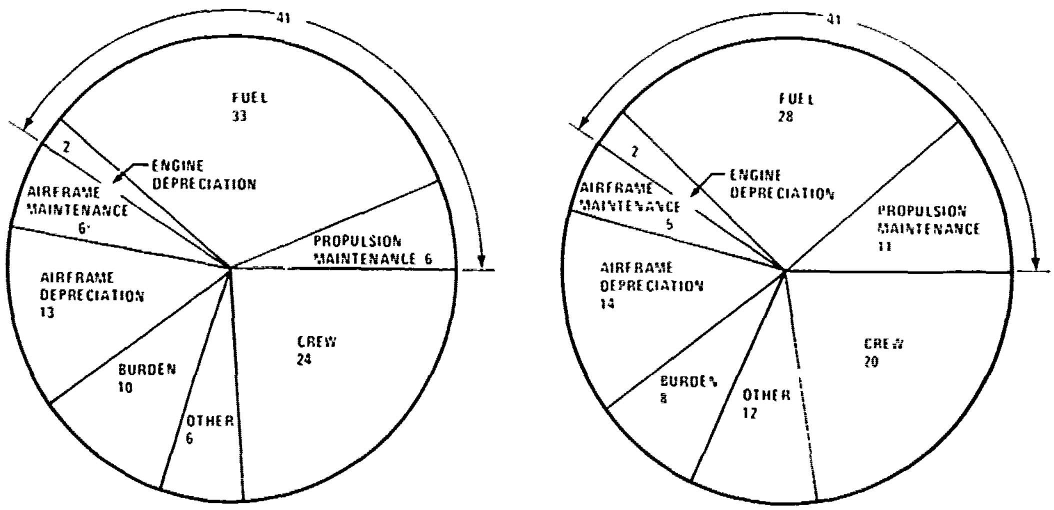
The "A Check", or pre-flight walk-around, is a daily occurrence and is, therefore, directly related to the utilization rate. The more in-depth "B Check" interval has remained fairly constant at about 50 hours for the C-9A, while Delta's interval has increased from 100 to 250 hours. Successive increases in the Delta "C Check" interval have raised this number to 1050 hours, while the C-9A remains at about 300 hours. Similarly, the "D Check" interval for Delta now stands at about 13,000 hours, while the C-9A remains at about 5000 hours.

The difference in maintenance action intervals leads to consideration of approaches to increase maintenance efficiency. The most obvious means of closing the gap between the DC-9 and C-9A intervals is to increase the C-9A intervals, based on the military and commercial maintenance data banks. This may be tempered somewhat by the C-9A home base support system versus the multi-base support facilities available to the DC-9, but longer intervals are a definite possibility. Another procedure, practiced commercially, is to reassign selected maintenance checks into the next longer interval inspection category.

Utilization is a function of the fleet size and the overall mission requirement. Military fleet sizing is predicated on emergency surge requirements and this may lead to larger fleets and less efficient peacetime operation of the individual airplanes. However, although the basic C-9A aeromedical evacuation mission is highly specialized, the aircraft also has a significant passenger transport capability with a simple available interior reconfiguration. The C-9A is thus capable of mult-mission use which would increase its utilization and overall effectiveness.

2. Propulsion System Costs

A very large portion of aircraft operating and maintenance costs are attributable to the propulsion system. It was expected that the introduction of high bypass ratio (HBR) engines for wide-body transports would result in economic benefits not provided by the low bypass engines installed on the previous generation of narrow-body transports. However, the portion of direct operating costs due to the propulsion system has remained constant at about 41 percent, Figure 23. With today's economic and energy problems, pressures are increasing to achieve the lower direct operating costs believed possible.



LOW BYPASS ENGINES
NARROW-BODY TRANSPORTS

HIGH BYPASS ENGINES
WIDE-BODY TRANSPORTS

1.00 -- COST PER REVENUE TON-MI — 0.97

Figure 23. Distribution of Commercial Aircraft Direct Operating Costs-1974

From 1973 to 1974, the fuel price rose from 12.8 to 21.8 cents per gallon, a 70 percent increase. Although a 30 percent improvement in fuel consumption has been achieved in the newer engines, the benefits thus gained have been largely offset by the rising cost of fuel.

However, the improvements in fuel economies in the HBR engines have been achieved at the cost of added maintenance resulting from increased complexity and expensive materials. These engines have higher compressor pressure ratios and higher turbine temperatures than low bypass ratio engines. They have larger fan diameters and the blades are subjected to very high centrifugal stress levels.

The higher compressor pressure ratios require compressors with an increased number of stages and more complex aerodynamic design, including variable stator stages, variable depth case coating and thermally matching material for tip clearance control. Increased compressor pressure ratios also result in higher temperatures in the rear stages of the compressor. More advanced and costly designs are required to allow the compressor to successfully operate at these increased temperatures. These include sophisticated turbine and combustor cooling to maintain life without excessive performance and weight penalties, and closer tolerances between rotating and stationary parts to achieve the higher performance of HBR engines.

Historically, new engines show increasing maintenance cost during the first three years of operations as in-service problems of the initial design are being uncovered, Figure 24.

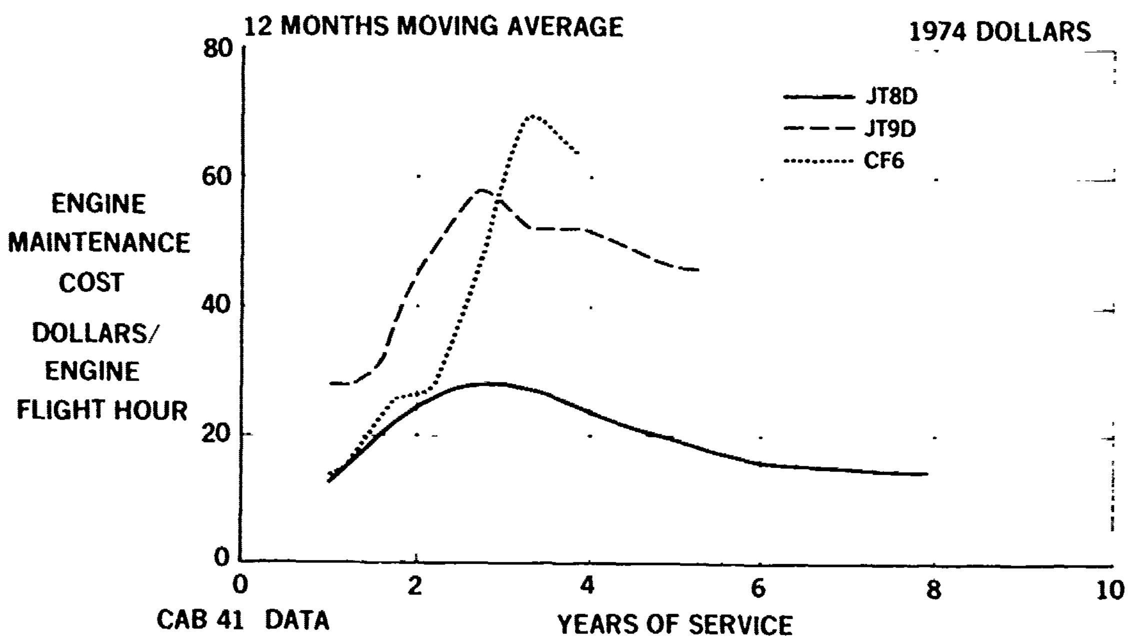


Figure 24. Engine Maintenance Cost Comparison

After about three years of operation, the engines show a decline in maintenance cost reflecting the incorporation of durability improvements. The low maintenance cost reported during the first year of service, though engine removal rates are high, is due partly to the fact that the actual repair costs are not reported by the aircraft operator as the engine is then under warranty. As engine operating problems begin to occur during the first and second year of operation, the subsequent identification of the problems, design of modifications, and incorporation of the modifications result in maintenance cost reduction occurring around three years of service.

Engine maintenance cost is the product of engine removal rate and cost of repair. Figure 25 reports the history of engine removal rate with years of service for three different engines and shows a common characteristic of all engines.

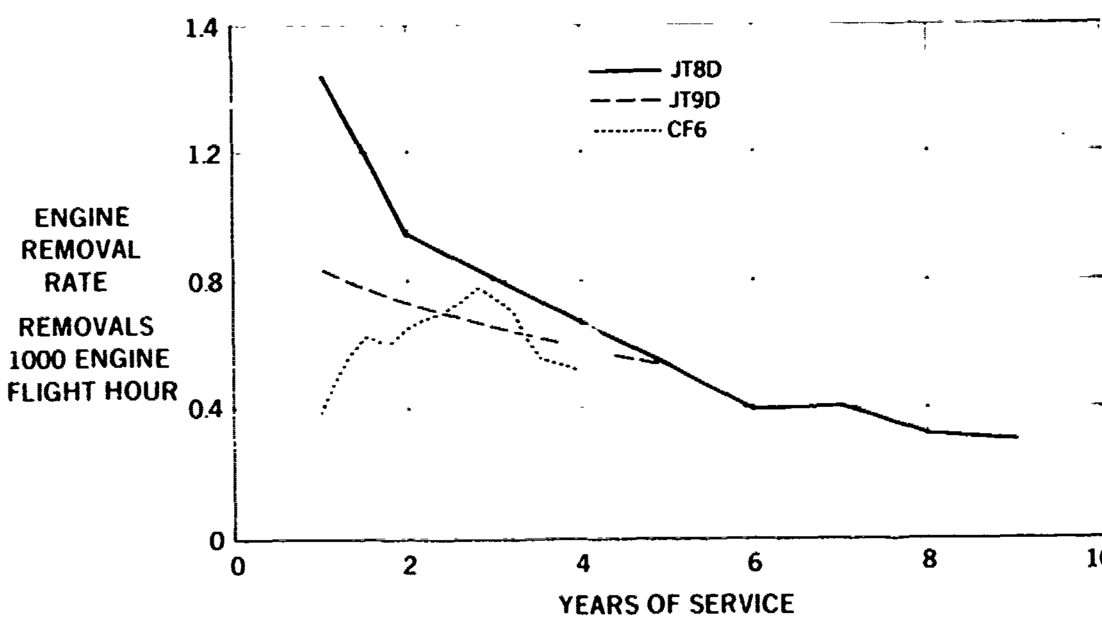


Figure 25. Engine Removal Rate Comparison

These data, for all models of the engines without regard to power setting or flight length, show high engine removal rates at entry into service and then a reduction and leveling off. This reflects the discovery of engine operational problems and the incorporation of modifications to improve reliability. It should be noted that the HBR engine with its higher operating temperatures and increased complexity had lower removal rates than the low bypass engine at entry into service.

Engine maturity, the point in time at which engine removal rate becomes relatively constant, is normally reached in about six to seven years of commercial service as shown by the JT8D. It is believed that the HBR engines will reach maturity in about the same time span or earlier and have engine removal rates comparable to less complex low bypass engines.

The factors influencing engine removals are engine power levels and flight length. Shorter flights require more takeoffs which impose more thermal cycles on the engines plus a higher percentage of climb power usage. Also, shorter flights result in higher engine operating temperatures than occur during longer cruise stages.

Figure 26 shows a representative engine removal rate variation as a function of stage length. Flight cycles of 4½ hours may result in as much as a 33 percent reduction in engine removal rate when compared to 1½ hour flight cycles.

When an engine is selected for a given aircraft, considerations include payload/range, takeoff, climb and cruise requirements. However, in actual commercial service, the aircraft is very seldom operated at its full payload/range capability, Figure 27.

For this type of usage, it is feasible and practical to reduce engine power for takeoff and climb and still provide the required aircraft compatibility. In other words, the engine is, in effect, oversized for the typical aircraft operation and can be operated at reduced power or "derated". Increased numbers of airline operators are operating engines

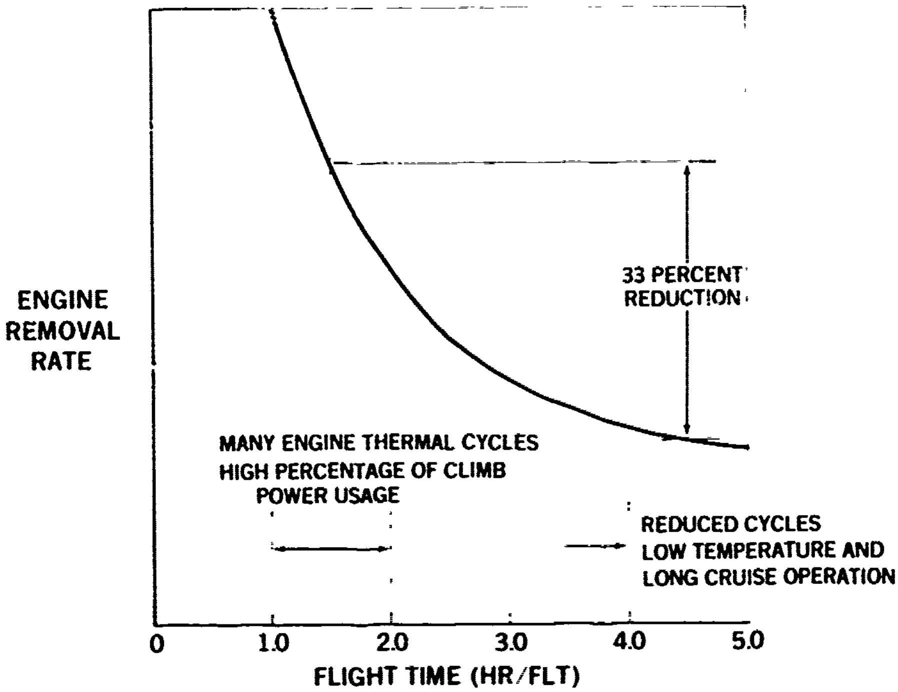


Figure 26. Effect of Flight Duration on Engine Removal Rate

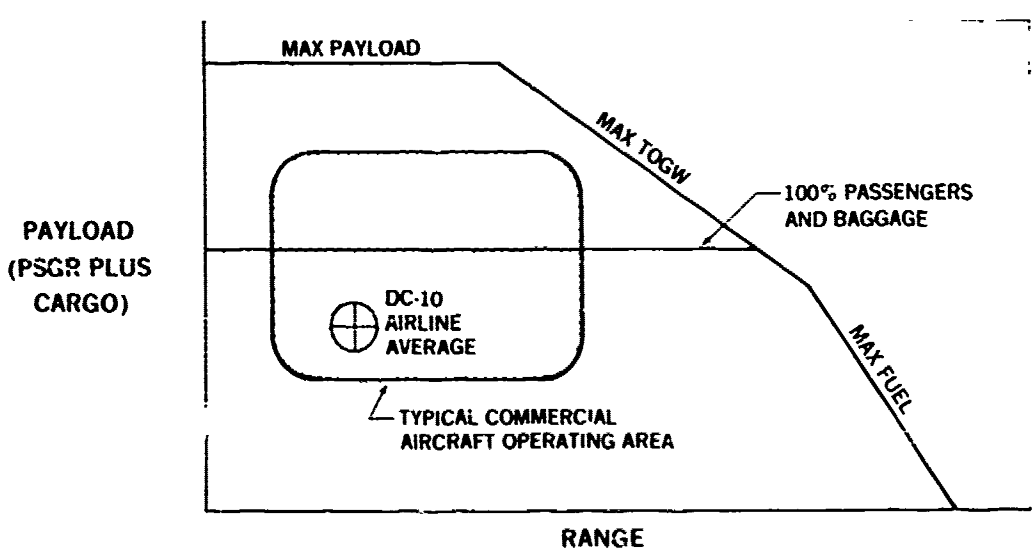


Figure 27. Typical Commercial Payload/Range Operating Area

at reduced power whenever possible because the effect of reduced power operation upon engine maintenance costs is substantial.

The maintenance characteristics shown in Figure 28 are representative of derated HBR engines. The engine removal rate is significantly affected by derating at the lower flight stages.

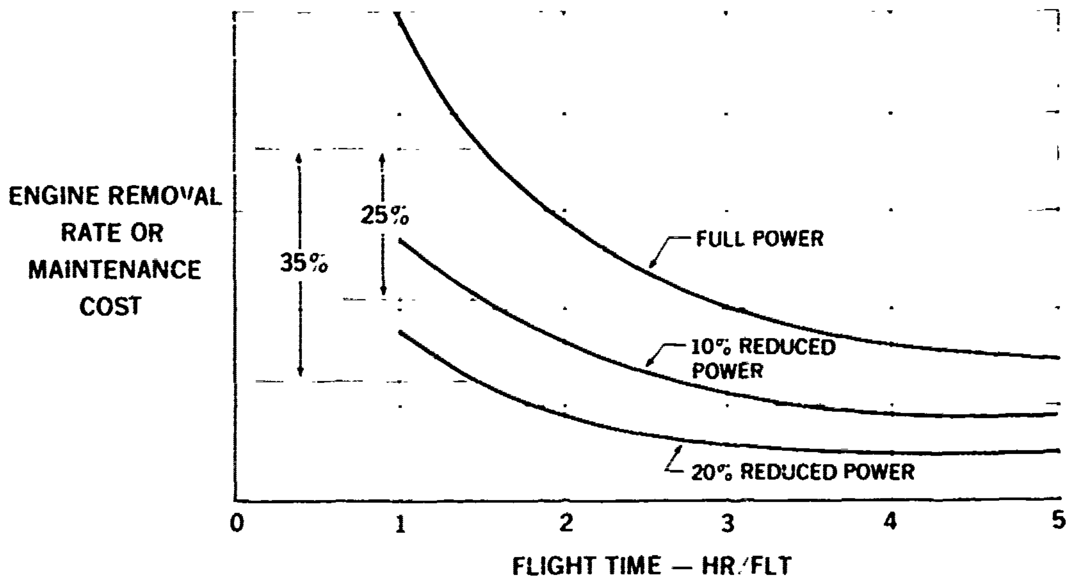


Figure 28. Effect of Flight Duration and Power Setting on Maintenance Costs

Lowering the engine thermal and stress levels when the engine is experiencing high cyclic operation is responsible for the large derate benefit. Also, short flight lengths provide the best opportunity for reduced engine power levels since aircraft takeoff gross weights are often the lowest. As the flight length becomes longer, the number of thermal cycles reduces and time at the lower cruise power increases. Thus, for the longer flight, the effect of reduced engine power is less significant on engine removal rates.

SECTION IV
IMPACT ANALYSIS

Task 4 of the study requires development and analysis of a "typical" military aircraft program to quantify the differences in schedule, resources and cost that result from application of selected commercial practices. However, the development of a "typical"military program for an impact analysis poses at least two major problems. First, to elicit meaningful estimates from the various organizations who are involved in any major program (Engineering, Manufacturing, Tooling, Test, Product Support, Material, Subcontracts, Management, etc.), technical and program approaches would have to be developed to significant levels of detail. Without such definition, the group estimates would include contingencies of varying magnitudes, which would greatly reduce the validity of the resultant differences. The generation of this amount of synthetic program data, and the attendant estimating exercise are beyond the scope of this study.

However, the AWACS program permitted a meaningful comparison within the scope of the program effort. The rationale for separating the mission-peculiar portions of AWACS from the air vehicle was established in Task One. The detailed AWACS proposal was available to provide specific schedule and manpower estimates. To match the available AWACS data, there were sufficient DC-8 design, test and operational data. Therefore, military and commercial derivations of an AWACS air vehicle have been studied to provide the required comparison.

A. SCHEDULE

The AWACS program actually consisted of several subprograms, one of which, that for DDT&E, may be considered analogous to the commercial effort from go-ahead to certification. The details of the 58-month DDT&E program for the total AWACS system are shown in Figure 29.

When only the air vehicle was considered, it was obvious that the 3-month Avionics Installation and the 5-month System Demonstration activities were not necessary. Because of the reduced complexity of the system, another three months were cut from the development time and split arbitrarily between Ground Test and Air Vehicle Development. The result was a decrease of 11 months in the schedule.

The "commercial" AWACS program schedule was derived from the DC-8-61 and DC-8-62 development schedules, Figure 30. As mentioned previously in Section II-E, even though the overall design complexity was not high, the -61 was the first stretch version of the basic airframe and the design and test programs reflected appropriate caution. The 25-month program for the -61 represents a typical balance between the noted milestones.

The -62, with its higher design complexity, had a slightly longer schedule than the -61, but still showed essentially the same milestone balance.

When estimating the schedule for the commercial AWACS, the -62 schedule was used as a base. The increased design complexity of AWACS was reflected in a slightly longer time to 90 percent release. However, it was felt that the fabrication, assembly, test and development time periods should not be increased nor should the flight test duration. The result was a 3-month longer schedule for the more complex AWACS.

B. MANPOWER

In establishing the ground rules for the Impact Analysis, it was necessary to modify the previously discussed rationale by which the AWACS mission system design manpower requirements were separated from the total system, Figure 31.

Originally, the Training, Support Equipment and Refurbishment efforts were included. However, there are no counterparts on a commercial program so they were excluded from the impact analysis. Also, the complete System Engineering efforts were deleted from the original breakdown. In establishing the Impact Analysis rationale, it was determined that the portion of System Engineering effort dedicated to support of the air vehicle studies should be included.

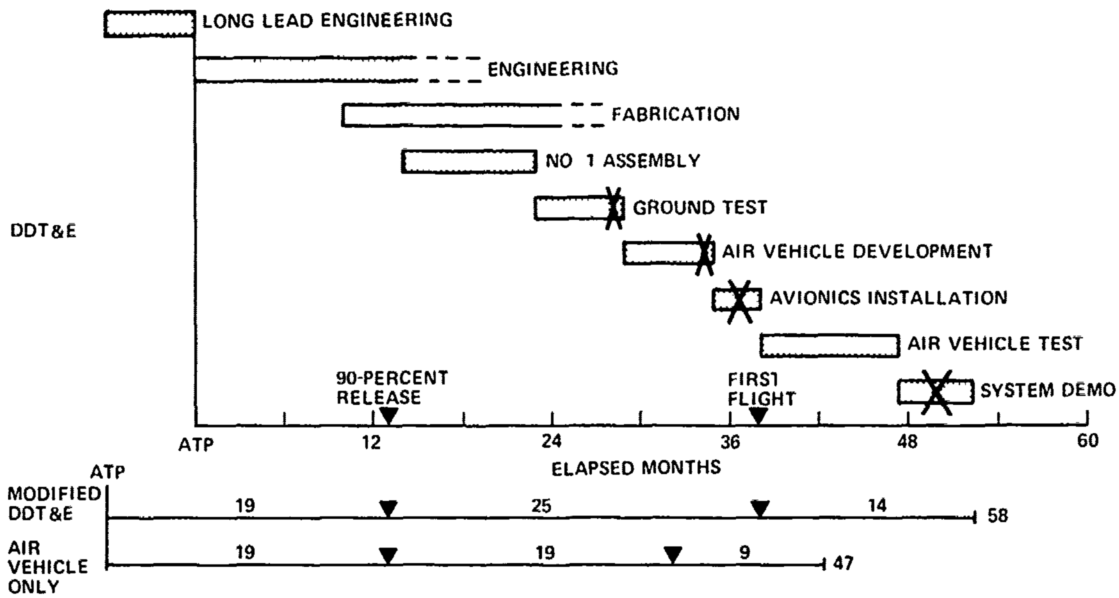


Figure 29. Military AWACS Schedule

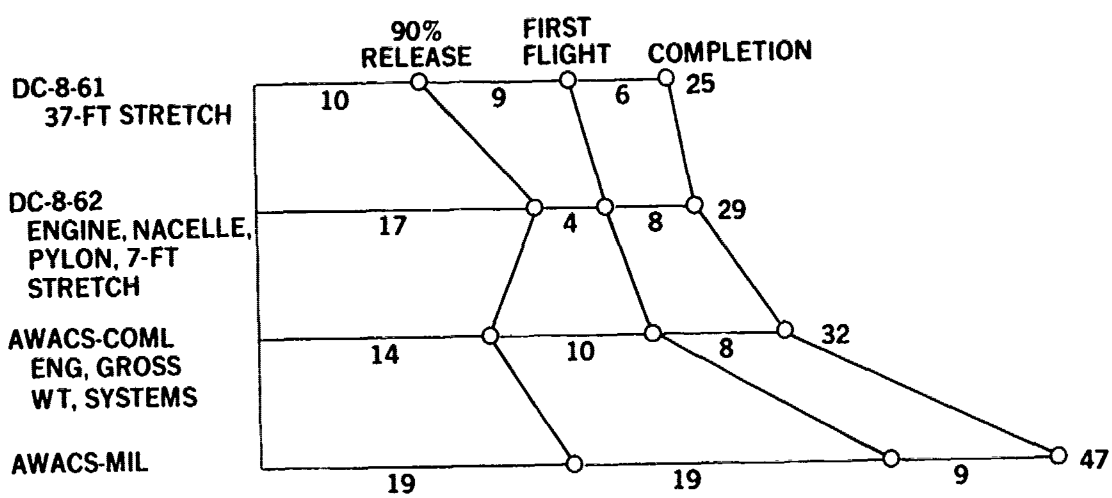


Figure 30. "Commercial" AWACS Schedule

WBS ELEMENT	AIR VEHICLE		CONFIG		AVIONICS	SYS ENGG	ADM	SYS TEST	
	DES	ANALYSIS	DES	SUP				LAB	FLT
AIR VEHICLE	72%	92%	59%	40%	4%	—	94%	49%	51%
~~ROTODOME~~	~~4%~~	~~8%~~	~~—~~	~~—~~	~~3%~~		~~1%~~		
~~MISSION SYSTEM~~	~~6%~~	~~—~~	~~—~~	~~1%~~	~~71%~~	~~97%~~	~~4%~~		
~~AVIONICS INSTEG~~	~~18%~~	~~—~~	~~41%~~	~~59%~~	~~22%~~	~~3%~~	~~1%~~		
SUBTOTALS									
SYSTEM TEST								—	—
SYS/PROJ MGMT									
DATA									
~~TRAINING~~									
~~PECULIAR SUPP EQ~~									
~~COMMON SUPP EQ~~									
~~SYS REFURB~~									
~~GRD ENTRY SYST~~									
~~COMPUTER PROG~~									
~~BRASS BOARD~~									
~~SYSTEM DEMO~~									
SUBTOTALS	X72%	X92%	X59%	X40%	X4%	X 47%	X 94%	X49%	X51%
TOTALS									

TOTAL ENGG HOURS FOR AIR VEHICLE

TOTAL TEST HOURS

Figure 31. Military AWACS Impact Analysis Rationale

The "commercial" AWACS design engineering manpower effort was established by applying a representative commercial factor for hours per pound of cost weight to the cost weight change. The "commercial" AWACS test manpower was developed from similar commercial test programs.

The design engineering manpower distributions for the military and commercial programs were developed using a computer program which adjusts time spans and distributions in relation to a selected base curve. A base curve for the current program was selected from a family of historical curves of commercial development programs. One of the DC-10 curves was selected for the Impact Analysis as it reflects a more current approach than that followed on the DC-8 program. That is, considerably more analysis and documentation was required on the DC-10 and this more nearly approaches current military practice.

Three major milestone events after go-ahead are considered: 90 percent release, first flight and completion. The percentage of the total effort associated with each milestone is fixed in accordance with the base case. The computer then adjusts the time span to match the new program and distributes the manpower accordingly.

The estimated engineering design manpower for the two programs was distributed over the schedules by the automated staffing program to illustrate differences in peak manpower, plus that required at each milestone, Figure 32. The military program shows a higher level of manpower over an additional 4 months at the 90 percent release point. At the time of first flight, the manpower levels are approximately equal, but the additional 14 months required by the military program greatly increases the expenditure. The military program peaks at about 690 men and requires an additional 1,020,000 hours to complete.

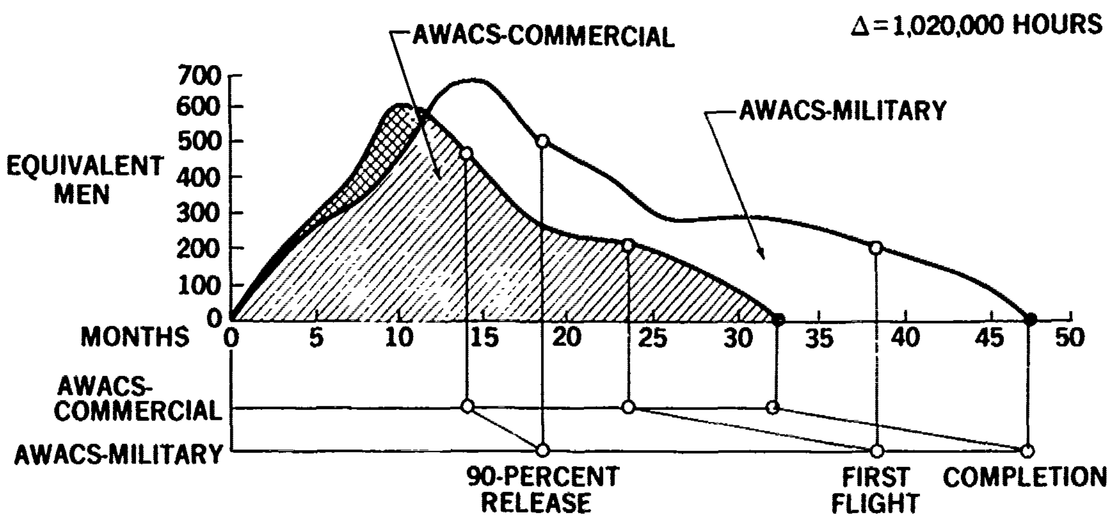


Figure 32. Design Engineering Manpower Distribution

The laboratory test effort for the commercial program was based on a blending of the DC-8-61 and -62 lab test program efforts, then compared to that developed from the military AWACS proposal. The distributions were based on the development schedules and specific requirements of the military and commercial programs, Figure 33.

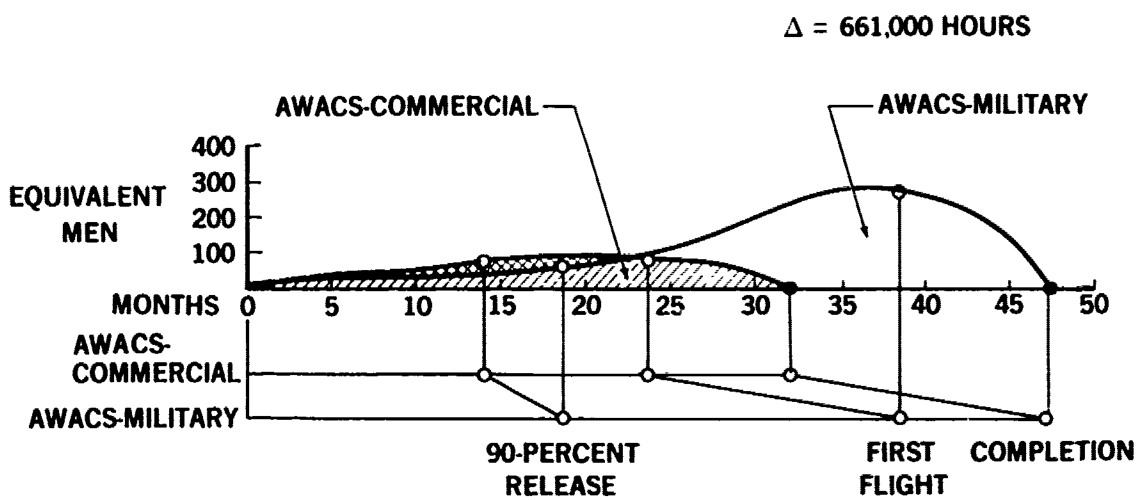


Figure 33. Laboratory Test Manpower Distribution

The military program reflects full compliance with the USAF Aircraft Structural Integrity Program (ASIP) approach except for the 150 percent design limit load tests; it includes full scale static tests up to 100 percent design limit load. The commercial program reflects the replacement of a significant amount of testing by analysis. Sufficient testing to verify specific analytical results is accomplished, however, the scope and amount of detail are considerably less than that required by MIL-SPEC. The military approach requires 661,000 additional hours of laboratory testing.

As in the case of laboratory testing, the flight test distributions were based on a combination of the DC-8-61 and -62 programs for the commercial AWACS, while the military program was based on the proposal, as modified for the air vehicle portion only, Figure 34. The larger military program reflects the MIL-SPEC requirement for a complete structural demonstration, plus a fully

Δ = 478,000 HOURS

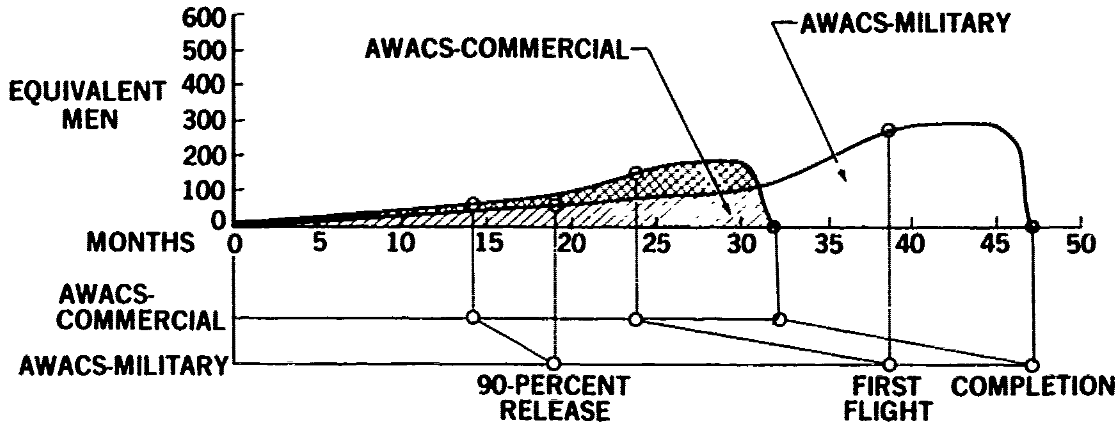


Figure 34. Flight Test Manpower Distribution

instrumented Category II test program. The commercial flight test program, like the lab program, relies much more heavily on analysis verified by selected test points. An additional 478,000 hours is required for the military flight test program.

The sum of the additional hours for lab and flight testing, 1, 139,000 hours, is almost 17 percent greater than the increase in engineering design hours. As a rule of thumb, the test effort on a commercial program is equal to about 50 percent of the engineering design effort; however, on the military AWACS, the test effort is equal to more than 70 percent.

The cumulative differences in design and test manpower requirements between the military and commercial AWACS programs are shown in Figure 35. Especially noticeable is the extent of the more involved, longer test program attributable to MIL-SPEC compliance.

The full impact of the greater magnitude, longer schedule military efforts can be seen more clearly than in the individual comparisons. This figure shows that the military approach would require almost twice as many engineering and test man-hours as a commercial approach to the same program.

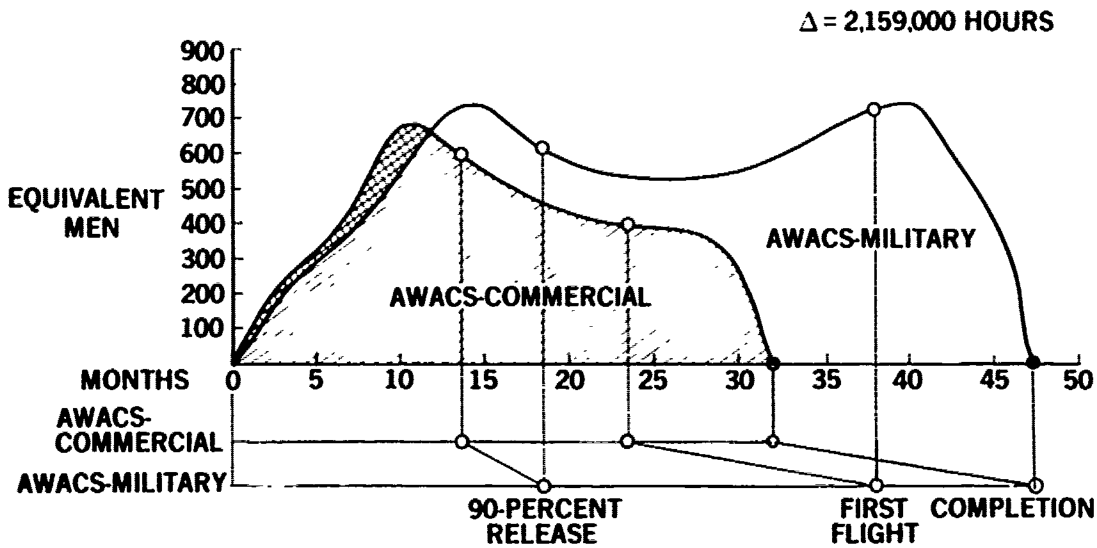


Figure 35. Composite Design/Test Manpower Distribution

TABLE 20. SAVINGS FROM COMMERCIAL-TYPE PRACTICES

		TIME	COSTS
SCHEDULE	:	15 MONTHS	
DESIGN ENGINEERING	:	1,020,000 HOURS	$20,461,200
TESTING	:	1,139,000 HOURS	22,848,340
DIRECT COSTS (TEST)	:	—	2,800,000
	TOTALS	2,159,000 HOURS	$46,109,540

C. COSTS

The differences in time and dollars for the military and commercial AWACS program are shown in Table 20. The commercial AWACS program, following the general practice for DC-8 derivative aircraft, could be completed approximately 15 months sooner than the military program. The 2,159,000 hour difference for design and test efforts equates to more than $43,000,000 using the aerospace industry 1973 average hourly rate. When $2,800,000 additional direct costs (materials, pilot's pay, facilities, per diem, etc.) are included the total difference exceeds $46,000,000.

Engineering design and test efforts generally make up from 50-60 percent of the costs of a commercial development. Thus, the overall cost of the military AWACS program could exceed that of a commercial-type approach by $75,000,000-$92,000,000.

APPENDIX A

REFERENCE MATERIAL

A-1 GENERAL PAPERS AND ARTICLES

1. "Parametric Equations for Estimating Aircraft Airframe Costs", Rand Report R-1693-PA&E, May 1975

2. "A Summary of Lessons Learned from Air Force Management Surveys", AFSCP 375-2, June 1963

3. "Automated Staffing", Douglas Report L8ME, dated 5 November 1970

4. "Impact of Commercial Aircraft Maintenance and Logistic Support Concepts on the Life Cycle Cost of Air ASW Weapons Systems", National Security Industrial Association Ad Hoc Study, dated 1 November 1975

5. "Low Cost Manufacturing Design - Aircraft Considerations", Douglas Report MDC J4412

6. "Propulsion System Operational Costs for High Bypass Engines in Commercial Applications", Douglas Paper F-6426, dated November 19, 1975

7. "Total Package Acquistions Concept", Logistics Management Institute Task 65-31, November 1965

8. "An Assessment of Contract Definition and Total Package Procurement", USAF Ad Hoc Group Report, 31 January 1967.

9. "Report by the Blue Ribbon Defense Panel to the President and the Secretary of Defense on the Department of Defense, Aerospace Industries Association Administrative Memo No. 70-33, 28 July 1970

10. "Report of the Commission on Government Procurement", 31 December 1972

11. "Design to Cost, Commercial vs. Department of Defense Practice", Defense Science Board Task Force Report, 15 March 1973

12. "Project ACE-Findings and Actions" Air Force Systems Command (AFSC/AV) Report, July 1975

13. "Performance Control & Government R&D Projects: The Measurable Effects of Performing Management and Engineering Techniques", E.A. Gerloff, IEEE Transactions on Engineering Management, Vol. EM-20, No. 1, February 1973

14. NSIA Report re Development of Major Defense Systems, October 1973.

15. CODSIA letter re Source Selection, April 1974.

16. CODSIA letter re Acquisition Management Systems and Data, June 1974.

17. CODSIA letter re DOD Acquisition Management Systems and Data, February 1975.

18. CODSIA letter re OMB Acquisition Management Systems and Data, April 1975.

19. Testimony in Behalf of AIA and EIA before the Office of Federal Procurement Policy, December 1975.

A-2 MILITARY PROGRAM DATA

1. AWACS Master Program Plan, Douglas Program Directive S5000, dated 2 January 1970

2. "VS(X) Weapon System Program Plan", Douglas Report 3600-1, Volume II, Dated 16 April 1968

3. "AWACS CDP Data Production Analysis", unpublished Douglas paper.

4. "AWACS System Engineering and Design Plan", Report DAC-68072A, Volume I, dated 9 January 1970

5. "Preliminary Military Requirements Analysis for Airborne Warning and Control Systems", Douglas Report DAC 56064, dated 15 January 1967

6. "Program - Second Air Force Review - AWACS Contract Definition Phase, 16-18 June 1969

7. "AWACS Request for Proposal", F19628-68-R0001, dated 14 February 1968, Revised 3 May 1968

8. "VC-X Request for Proposal", F-33657-74-R-0346, dated 19 November 1973

9. "AWACS Aircraft Structural Integrity Program Master Plan", Report DAC-0/C 68089C, 2 March 1970

10. "AWACS Structural Design Criteria Report", Douglas Report DAC 68061, dated 20 August 1969

11. "AWACS Low Cost Approach", Douglas Briefing Charts.

12. "CX-2 Proposal", Douglas Report 3478, dated 14 June 1967

13. "CX-2 Request for Proposal", F33657-67-R-1078, dated 13 May 1967

14. "Advanced Medium STOL Transport Prototype", Request for Proposal," F33657-72-C-0833-P00003, dated 8 January 1973

15. "VC-9C Memorandum of Understanding", dated 9 April 1974

16. "DC-9 Medium Multi-Range Jet Transport for United States Navy", Detail Specification DS-3902, revised 1 May 1973

17. "USAF C-9A Military Jet Transport for Aeromedical Evacuation", Detail Specification DS-3802, revised 1 September 1972

18. "VC-9C Medium Jet Transport for United States Air Force" Detail Specification DS-3911, revised 15 January 1975

A-3 COMMERCIAL PROGRAM DATA

1. "Airworthiness Standards: Transport Category Airplanes Aviation Regulations, Volume III, Part 25

2. "Representatives of the Administrator, Federal Aviation Regulations, Part 183", dated May 1974.

3. "Designated Engineering and Manufacturing Inspection Representatives", Federal Aviation Administration, Western Region Order WE AE 8100.2A, dated 27 March 1972.

4. "DC-9 Certification Data Submitted to FAA", Douglas Aircraft Company Report DAC-33783

5. FAA Type Certificate Data Sheet

    a. 4A25 (DC-8)

    b. A6WE (DC-9)

    c. A22WE (DC-10)

6. "Douglas Jet Transports - Scheduled Maintenance Programs", Product Support Report 761-63, dated July 1975

7. "Four Engine Jet Transport Model DC-8-62", Detail Specification DS-3035, revised 27 June 1969

8. "DC-9 Short to Medium Range Jet Transport", Detail Type Specification DTS-3650, revised 1 May 1974

9. "McDonnell Douglas DC-10 Series 30 Intercontinental Jet Transport" Detail Type Specification DTS-54006, dated 1 August 1974

10. "The DC-9 Reliability Program", Douglas Paper 3320, dated 17 March 1965

APPENDIX B

RECOMMENDED DOCUMENTATION CHANGES

Document - MIL-STD-480/481 - Configuration Control - Engineering Changes, Waivers and Deviations.

MIL-STD-482 - Configuration Status, Accounting Data Elements and Related Features.

MIL-STD-483 (AF) - Configuration Management Practices for Systems, Munitions and Computer Programs.

DoDD 5010.19 - Configuration Management.

DoDI 5010.21 - Configuration Management Implementation Guidance.

Problem:

The above standards provide guidance for traceability of engineering changes, waivers and deviations to functional and physical attributes of a defense system/subsystem. The standards are frequently not applied at all or applied fully without tailoring the traceability requirements to the needs of the particular system procurement. In either case, improper management control of configuration status can become extremely expensive and ineffective. On the one hand, changes, waivers and deviations are insufficiently controlled. Conversely, great volumes of unnecessary paperwork are procured just to acquire the relatively small volume of paperwork really needed for adequate control.

In some instances complete traceability on all kinds of hardware such as washers, bolts and nuts, have been required despite the fact that the systems were well into production and no performance difficulties had been encountered.

MIL-STD-483 duplicates in part MIL-STD-480, -481, -482 and -490.

When employed prior to design freeze, which usually occurs near the end of Full Scale Development, MIL-STD-483 inhibits design changes at a time when changes should be made. There is no need for a formal configuration management plan and its inherent requirement for configuration control to trace development hardware changes.

Particular exception is taken to the reference to MIL-STD-499, System Engineering Management. See write-up on MIL-STD-499 (Appendix B-3).

Recommendation:

Consolidate the subject documents into one standard for production configuration control. Full Scale Development configuration control should be in accordance with the NSIA-recommended DoDD 5000.., Development of Major Defense Systems. (Reference f).

Estimated Cost Reduction: 3-10 percent of Full Scale Development Costs. Typical cost is 4 percent.

Document - MIL-STD-490A (Proposed), Specification Practices, 1 August 1975

Problem:

1. The document does not prohibit the premature specification of detail requirements at the beginning of Full Scale Development.

2. A major concern is the complexity of the subject matter, created mostly by the confusing identification of specification types. The following example in reference to the table on page 4 of the draft illustrates this point. A Prime Item (Type B1) development specification is used in the Development and Production phase. This type of specification is also called a Functional Configuration Identification later in the text. A Prime Item Function (C1a) product specification is used in the Development and Production phase and a Prime Item Fabrication (C1b) product specification is used in only the Production phase. This type of specification is also called Product Configuration Identification later in the text. Note that: (a) the alpha-numerical designations have no significance since the titles of the specifications describe the type; (b) the phase terminology is incorrect, i.e., Development phase should be Full Scale Development and Production phase should be Production/Deployment; (c) a development specification as described in the text is actually a performance specification, i.e., they are redundant; (d) a product specification as described in the text is a design specification; and (e) the terms Functional Configuration Identification and Product Configuration Identification are redundant classifications for the various types of specifications.

   Additional examples of confusion relative to the table on page 4 include: (a) an aircraft is a prime item while a ship is not; (b) there is a requirement for performance specifications on non-complex items when drawings are probably adequate; and (c) there is a requirement for a ship performance specification but no requirement for a design specification.

Recommendation:

It is strongly recommended that the document be purged of jargon and the number of specifications be drastically reduced. This would entail complete revision of the document. The document should incorporate guidance to preclude premature specification of detail at the beginning of Full Scale Development.

Estimated Cost Reduction:

* % Full Scale Development Costs.

* The unnecessary cost of premature specification detail is included in the cost estimates for Appendix B-1.

<u>Document</u> - MIL-STD-499A (USAF) Engineering Management, 1 May 1974.

<u>Problem</u>:

- Appears to be in conflict with DepSecDef Memorandum of 7 April 1970 (pages 6-10).
- Was issued without formal DDR&E approval. DoDD 5000.1 designated DDR&E to approve system engineering policies.
- Is incompatible with DoDD 5000.1 emphasis on outputs, hardware performance, testing, prototyping, etc., rather than paper procedures.
- Was issued in violation of DoDI 7000.6 requirement for Service Secretary approval.
- Is incompatible with DoDI 7000.6 requirement that this type document be output-oriented rather than procedure-oriented.
- Was issued in violation of DoD 4120.3M, Policies and Procedures for Standardization Documents, which states that "a military standard will not be used as the medium for imposing administrative requirements on contractors". Also, DoD 4120.3M requires tri-service coordination for military standards except in the case of "an immediate need where urgency does not permit coordination to be affected". The need and urgency for MIL-STD 499 are very questionable.
- This standard portrays a top-down paperwork approach to system engineering without recognizing the real world of trial and error, compromises, iterative processes, etc. Good system engineering requires flexibility. <u>If there is anything that should not be standardized, it is system engineering management</u>.

<u>Recommendation</u>:

Rescind.

<u>Estimated Cost Reduction</u>:

1-8 percent of Full Scale Development costs - depending upon the reasonableness of the validation/demonstration/surveillance requirements.

Document - MIL-STD-1521 (USAF) - Technical Reviews and Audits for Systems, Equipment, and Computer Programs, 1 September 1972.

Problem:

The standard prescribes the requirements for the conduct of Technical Reviews and Audits on Systems, Equipments, and Computer Programs when using MIL-STD-499A (USAF), System Engineering Management, and MIL-STD-483, Configuration Management.

This document specifies the same review requirements for all programs regardless of size, type or complexity. In addition, many of the things specified should be left to the discretion of the contractor, e.g., how to conduct design reviews, prepare an agenda and minutes, where to hold meetings, who should attend, etc.

Recommendation:

Cancel or revise per the following excerpt from NSIA-recommended DoDD 5000.X, Development of Major Defense Systems.

> Design Reviews - Design reviews are necessary to assess the capabilities of Full Scale Development (FSD) efforts to meet changing military needs and to assess the progress toward achieving current contract objectives. Reviews shall be conducted by a limited number of engineers and decision-makers familiar with the program. Informal communication regarding the evolving design configuration is encouraged to minimize the time and dollar cost of formal reviews and to provide early resolution of problems. Normally, formal design reviews shall be:
>
> (1) Limited in scope to address areas of major risk, design freeze, overall progress, changes to user needs, and major problems.
>
> (2) Limited in frequency to preclude unnecessary expenditure of time and money, yet frequent enough to minimize the impact of system changes and maintain adequate program understanding and control. One or two formal design reviews during Advanced Development (AD) and three or four during FSD are usually sufficient.
>
> (3) Scheduled so as to benefit from Technical Confidence Milestone events and to support major program decisions with sufficient notice to allow the prime contractor to include suppliers and subcontractors efforts.

Estimated Cost Reduction:

0.3% of Full Scale Development costs.

Document - MIL-Q-9858A, Quality Program Requirements, 16 December 1963.

Problem:

Total application of this specification too early in a program can contribute to unnecessary program costs.

Recommendation:

The quality program should be established by the Program Manager's approval of a contractor-recommended plan made in accordance with the DoDD 4155.1, "Quality Assurance". The requirements should be tailored to the specific needs of each individual program and graduated from Advanced Development through Full Scale Development.

Estimated Cost Reduction:

0.5 - 4.0 percent of FSD Program Cost.

Document - MIL-STD-1520A, "Corrective Action and Disposition System for Nonconforming Material", 21 March 1975.

Problem:

The subject military standard has been issued after extensive coordination with industry over the past four years. This standard still retains many provisions which were objected to by industry during the coordination period. These provisions, if contractually imposed, will have an adverse impact on existing corrective action and disposition systems for nonconforming material. Organizations affected are Quality Assurance, Manufacturing, Material, Engineering, Estimating and Contracts.

Provisions of this standard having the greatest impact are as follows:

(a) Generation, collection, and maintenance of nonconformance cost data (actual and/or relative cost constants).

(b) The Government is no longer a member of the Material Review Board (MRB); however, the Government requires review and approval of repair procedures and also reserves the right to reject the item after accomplishment of the repair.

(c) Establishment of a new Corrective Action Board (CAB) comprised of contractor management representatives.

(d) Preliminary review "use-as-is" dispositions are prohibited.

(e) Preliminary review "repair" dispositions are limited to "standard repairs" which have been approved by the Government.

(f) Government reserves the right of disapproval over many aspects of the contractor's system.

Recommendation:

Delete the subject standard or as a minimum, reevaluate and implement industry comments to establish a more cost-effective approach.

Document - MIL-STD-1528 - Production Management, 1 August 1972.

Problem:

The production management system is subject to the disapproval of the government production mangement representative whenever the contractor's procedures are found to be inadequate or do not accomplish their objectives. This provision of the standard is most arbitrary, in that government representatives can disapprove the production management system based upon their interpretations of the inadequacies of the contractor's procedures. This authority is granted without adequate justification since no criteria are specified for determining procedure inadequacies.

The contractor is required to establish and use an internal review process to monitor production management system effectiveness. This requirement is redundant with requirements of MIL-Q-9858A.

Throughout the standard, the contractor is told how his organization shall be established, e.g., "Production engineering shall be an integral part of the production management system". Appropriate contractual management systems specify "what" is required of a contractor, not "how" the contractor is organized or the procedures he must use. Maximum use should be made of contractor's internal management systems.

The ambiguity of the standard, e.g., "Production criteria shall be established and producibility analysis shall be accomplished", presents considerable latitude for the local reviewing representative to establish what and how many producibility studies are necessary to satisfy the requirements of the standard.

Recommendation:

Cancel.

Document - MIL-STD-1535 (USAF), Supplier Quality Assurance Program Requirements, 1 December 1972.

Problem:

This standard was developed due to the opinion of Government personnel that industry was not adequately controlling suppliers. It has the effect of generating unnecessary costs on any program to which it is made applicable. Unnecessary costs result from excessive and restrictive "how to" instructions which are imposed on the prime contractor and from the flow-down impact on suppliers.

Recommendations:

Cancel. Document is not needed. If compliance of the prime contractor with MIL-Q-9859-A is established, the objectives of MIL-STD-1535 (USAF) are met, and the detail is scaled to the needs of the procurement.

Document - MIL-STD-1567, Work Measurement, 30 June 1975.

Problem:

It makes no provisions for acceptance of existing work measurement systems that have been used by most contractors for years.

The vagueness and ambiguity in certain areas of the standard offer considerable latitude to the Government reviewing representative in determining whether the contractors' systems meet the requirements of the standard.

The prescribed work measurement standards and the level of accuracy/coverage requirements are more appropriate in repetitive operations with long and sustained production runs, a rarity for the defense industry.

The standard will be extremely burdensome and expensive to install and maintain.

Recommendation:

Rescind.

Documents - MIL-F-8785 (ASG)-4, Flying Qualities of Piloted Airplanes.
MIL-S-8860 (ASG) Airplane Strength and Rigidity, General Specification for
MIL-S-8861 (ASG) Airplane Strength and Rigidity, Flight Loads.
MIL-S-5711 (USAF) Structural Criteria, Piloted Airplanes, Structural Test, Flight
MIL-A-8862 (ASG) Airplane Strength and Rigidity, Land Plane Landing and Ground Handling Loads, 18 May 1960.
AFSCM-80-1 Handbook of Instruction for Aircraft Designers

Problem:

These documents are representative of many which describe requirements for the design and development of new aircraft. Their application to the derivation of a military system from an existing commercial aircraft designed to differing FAA requirements may necessitate unnecessary redesign of the proven system.

Recommendation:

Apply only those paragraphs that are deemed critical to ensure that mission and safety requirements are met. Other sections should be referenced for guidance only.

APPENDIX C

SUPPLEMENTARY FINDINGS AND RECOMMENDATIONS

C-1 DATA ITEMS

Recommendation:

Data requirements should be selected on the following basis:

- Proven cost-effective on previous applications.
- Recommended by the DOD information users when the need is clear and the evolving program is well understood.
- Specified as deliverable items. It should not require any particular contractor procedure or otherwise specify the contractor's internal management systems.
- Suited to the contract type, procurement method, contract value, acquisition complexity, and life-cycle phase.
- Approved by the DOD Program Manager.
- Challenged and reviewed for OSD Policy in accordance with Secretary Clements' Memo of 17 July 1973.
- Delivered when actually needed for assessment.
- Accepted on the contractor's format. If use of the contractor's format is not cost-effective, assure the use of uniform (at interfaces among DOD components and industry) forms.

C-2 CONFIGURATION MANAGEMENT

Recommendation:

The appropriate level of program detail should be based on the following guidelines:

- Firm technical requirements should not be specified below the system level at the beginning of Advanced Developments nor the major subsystem level at the beginning of Full Scale Developments. Detailed requirements are appropriate only for production programs.

- Initial product requirements should be limited to those performance requirements and design constraints which are mandatory, and the generation of increased specification detail should be based on trades as development evolves towards production.

- Government change control of specifications should be provided to a level appropriate to the state of definition of the system.

C-3 GOVERNMENT REVIEWS

Recommendation:

Tailoring of major program reviews should be achieved during Full Scale Development when the Government's and Contractor's resources are available, time permits, and there is sufficient knowledge of the defense system and its progress. Reviews should be conducted by a limited number of engineers and decision-makers familiar with the program. Informal communication regarding the evolving design configuration should be encouraged to minimize the time and dollar cost of formal reviews and to provide early resolution of problems. Normally, formal design reviews should be:

- Limited in scope to address areas of major risk, design freeze, overall progress, changes to user needs, and major problems.
- Limited in frequency to preclude unnecessary expenditure of time and money, yet frequent enough to minimize the impact of system changes and maintain adequate program understanding and control. One or two formal design reviews during Advanced Development and three or four during FSD should be sufficient.
- Scheduled so as to benefit from Technical Confidence Milestone events and to support major program decisions (including SecDef's) with sufficient notice to allow the prime contractor to include suppliers and subcontractors.

C-4 MILITARY SPECIFICATION APPLICABILITY

Finding: Many Government documents are imposed by reference documents and not otherwise directly specified to a particular program. Tailoring such documents requires much effort and program knowledge. Properly tailoring the essential documents to a typical major program requires hundreds of engineers 18 months or more and can only be done by the contractor during FSD. Tailoring over 10,000 documents that get imposed via reference is impractical, even during FSD.

Recommendation:

Contractual requirements shall be specifically named in contracts. Reference documents shall not be contractual and shall be used for guidance purpose only.

APPENDIX D

MANAGEMENT QUESTIONNAIRE

M E M O R A N D U M

C1-263-LC-765
29 September 1975

To: Distribution

From: L. Carlyle, C1-263

Subject: COMPARISON OF MILITARY AND COMMERCIAL DESIGN-TO-COST AIRCRAFT PROCUREMENT AND OPERATIONAL SUPPORT PRACTICES

1. DAC is engaged in the subject study under contract to the Air Force Flight Dynamics Laboratory, Wright-Patterson AFB. The objectives of the study are to identify those military practices that are major cost drivers and to determine if less costly commercial practices may be substituted. The study is addressed primarily to programs involving both military and commercial derivatives of existing commercial transport aircraft.

2. Your assistance in this study is requested. A major element of the study is the large store of personal experiences and attitudes of key management people. The attached questionnaire is intended to provide a framework for gathering and collating these experiences. You, and/or other knowledgeable persons in your organization, are requested to answer the questionnaire in as much detail as time permits. The questionnaire is in two parts: General, and Specific. If you have a response to any question in either part, feel free to submit it regardless of functional distinction. References to previous studies, reports, briefings, etc. which deal with the subject will be appreciated.

3. Please direct any questions to the undersigned at Extension 31878, or to Al Chamberlain, Extension 35184. Your responses to the questionnaire are requested by 17 October.

L. Carlyle

L. Carlyle
Principal Investigator
(Mail Code 35-74)

LC:am

QUESTIONNAIRE
MILITARY/COMMERCIAL PROCUREMENT PRACTICE COMPARISON
PART I - GENERAL

Completed by ______________

1. With all the controls, regulations, specifications, documentation, does the military customer, as a general rule, receive a better quality product from industry? If not, what <u>do</u> they gain?

2. If assigned to, supporting, or with first hand knowledge of a commercial derivative program, is there anything specific on that program which is better or worse than that done or being done on a similar military program, i.e., DC-8 vs AWACS, DC-9 vs C-9A, C-9B, VC-9C, VS(X), AMST.

3. What is the ratio of administrative man-hours on military/derivative programs to those on commercial programs?

4. Can you name specific military program requirements that need to be revised, in part or in whole, which would result in reducing contract costs without reduction in quality? This could include deletion, updating, revising or rewriting by loosening or tightening tolerances, elimination of certain tests, reviews, reports, etc.

5. On the other hand, assuming the military program requirements are valid, are these better ways to comply? If so, how?

6. A nearly universal complaint on military programs is the long time it takes to get a decision. Is there a way that this lost time or time-awaiting decision can be equated to the cost on a program? How can this be improved and still allow DOD to maintain control?

7. Do the greater number of military specs, more quality assurance, and greater number and greater depth of tests provide a better product? Why?

8. Are there particular military specifications or standards which can be pinpointed as the causes of excessive costs?

9. What part of these specs and standards need to be changed and why?

10. Have you data or are data available from which the savings to Douglas (and consequently, to the government) can be determined (in manhours, dollars, flight time, elapsed time, or a combination of these), if the specs were changed?

11. Does the generally lower production rate of military programs increase the cost of the end product? If so, how much and what affects these costs? Is there an optimum rate?

12. It has been suggested that the government evaluate and validate each company in the industry periodically to avoid having to give the same basic data pertaining to program management, experience, skills, and other background data in every proposal. Do you agree with this approach?

13. Do you believe this change would have any impact on program costs? If so, where and how much?

14. If this policy were established and the government set up a central procurement data bank, what kind of information do you believe should be included; i.e., what kind of evaluation should be made? Limit your ideas to airplane manufacturers.

15. Does the lack of contractor involvement in long-range planning impact the cost of military products? What needs to be done to change this?

16. Comment has been made that on commercial programs engineers spend 100% of their time engineering while on military programs it is 40% engineering and 60% paperwork. Is this true in your experience? Does this mean it takes 2-1/2 times longer to do the same job? Are all engineers affected? Lead engineers? Supervisors?

17. A study on commercial programs indicated that over half of all engineering changes are made because of design errors. Does the necessity of having to comply with military specifications and requirements reduce this problem? What do you think will reduce errors effectively?

18. For both military and commercial programs -

    a. In your opinion, is an adequate balance established between performance and cost during the initial program planning?

    b. What is the process for major program decisions?

    c. Is a specific unit cost target established and worked toward?

    d. Are standardization and commonality emphasized?

19. What is your opinion on establishing a second source for high quantity military production items?

20. What is your major area(s) of responsibility (i.e., management, planning, design, testing, manufacturing, etc.)?

21. What portion of your total Douglas experience is on military programs? Within the last 8-10 years?

QUESTIONNAIRE
MILITARY/COMMERCIAL PROCUREMENT PRACTICE COMPARISON
PART II - SPECIFIC

A. PRICING

1. Does the government requirement for completion and audit of the 633 form generate more workload for the Pricing personnel working on a military program than those working on a commercial program? If so, how much and how could it be reduced?

2. Are more personnel required for costs and schedules support on military programs? If so, do you have suggestions on how to lower the workload?

3. On derivative military programs, the contractor generally is not reimbursed for the risk involved for holding positions in the production schedule. Have your recommendations on how this might be handled?

4. What effect would the inclusion of a commercial warranty program have on the price of military contracts? Would a warranty program be realistic for the military?

5. Is there a difference between military and commercial programs in the amount of time spent by Pricing for cost estimating in support of subcontractor/vendor work? Why?

B. MATERIAL

1. There is general agreement that the price of a part for a military program is more than a similar part for commercial programs. When buying a part from a vendor or subcontractor, what are the differences in requirements for commercial and military parts that cause the price differential?

2. How much different, percentage-wise, is the price?

3. What is your estimate on the portion of the price of a commercial part that is due to warranty program?

4. When DAC releases a specification for bid, does competition provide a bid that is realistic or do we require a price breakdown? Have we made our own estimate of the approximate cost? How is the successful bidder chosen?

5. With the additional specifications, do military parts have a greater acceptance rate? How much?

6. What reasons do suppliers give when they decline or resist bidding on parts for military programs?

7. Are there differences in the amount and form of test and acceptance data generated by a supplier for a military product? If so, what?

8. Assuming an equal end product, is the number of people greater for the Douglas Material Department for a military or commercial program?

9. There are indications that the government may be changing or waiving some procurement regulations in the case of derivatives. What ASPRs, etc., could be changed or waived that would help contractors procure parts at a lower price without affecting quality?

C. QUALITY ASSURANCE

1. What are the differences in QA assignments, workloads, and completeness of job between commercial and military programs?

2. What methods are used to compare the results of the QA efforts?

3. What is your estimate of the manpower cost difference for this effort between commercial and military programs?

4. For a military program, do the additional requirements, and the manpower to implement these requirements, result in lower support costs and/or a better airplane for the customer as compared to a commercial program with considerably less of this kind of effort during the design phase?

5. With the additional specifications, do military parts have a greater acceptance rate? How much?

6. Are there differences in the amount and form of test and acceptance data generated by a supplier for a military product? If so, what?

D. TESTING

1. Much has been written on the length of military flight test programs over commercial and subsequent increased cost but if we take out the maintainability, reliability, climatic and personnel subsystem tests (which the airline customers, in effect, do for us) the flight test programs contain about the same number of flight hours. There is also about the same calendar time between first flight and first delivery or certification. If this is true, what is the cause for the increased cost of a military flight program?

2. What changes do you believe the government should make to the present requirements for maintainability, reliability, PSTE and climatic and testing for them to be more cost-effective?

3. What test requirements which have been imposed on current derivatives do you consider valid for a new military program but superfluous for derivative programs?

4. The comment has been made that rigidity of military testing increases the cost. For instance, if a test cannot be completed due to equipment failure, the military may cancel the test while Douglas, on a commercial program, will alter the test program, without shutdown or landing, to accomplish another requirement. Does this occur often enough to warrant further investigation?

E. MAINTAINABILITY

1. For a military program, do the additional maintainability/maintenance requirements result in lower support costs and/or a better airplane for the customer as compared to a commercial program with considerably less of this kind of effort during the design phase?

2. What is your estimate of the manpower cost difference for this effort between military and commercial programs?

3. Can the commercial basic maintenance philosophy of fewer inspections and requirements and no-overhaul/fix-when-failed be realistically extended to the military environment, assuming similar utilization? Assuming lower utilization with a high readiness posture? Why, in each case?

4. What differences are there in the support provided to the customers by our field service engineers in military and commercial programs?

5. What are the differences in spares provisioning, stockage, usage and control?

6. Do the commercial and military maintenance manuals provide adequate and pertinent information in usable form to both types of customers? What is the ratio of cost for those manuals for similar aircraft?

7. Would the current commercial practice, that of obtaining engineering drawings and making or subcontracting peculiar ground support equipment, result in the same cost-effectiveness and quality for the military as it did for commercial programs? If not, why?

F. TRAINING

1. Assuming derivative programs and the training of experienced personnel, do the additional requirements, and the manpower to implement these requirements result in better trained military people as compared with similar people on a commercial program?

2. If the answer is no, are data available for which a cost comparison could be established? Is there a difference in cost to implement an equal level of training? Why?

3. Is anything being accomplished on commercial training programs that would benefit the military either in better training or less expensive training that could be adapted to the military programs or derivative programs? Please list with the advantages.

G. PUBLICATIONS

1. For a military program, do the additional requirements, and the manpower to implement them, result in better manuals for the customer as compared to a commercial program with considerably less of this kind of effort during the planning and preparation phases?

2. Is there a difference in manpower cost for publications between commercial and military programs? If so, what are the primary reasons? Can you identify specific requirements causing this difference?

3. Would the use of microfilm, as is common with commercial customers, work in the current military environment? If not, what changes would be required?

4. Do you have data on the savings to the commercial customer when the change from hard copy manuals to microfilm was made?

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